Spring 2015

How do I get to Vilcashuaman? Least cost path analyses of the Chinchaysuyu road from Cuzco to Vilcashuaman

Shelby Magee
Shelby.Magee@Colorado.EDU

HOW DO I GET TO VILCASHUAMAN?

Least Cost Path Analyses of the Chinchaysuyu road from Cuzco to Vilcashuaman

Shelby Magee

Department of Anthropology Honors

Photograph of the Chinchaysuyu road from the National Museum for the American Indian

Primary Thesis Advisor
Gerardo Gutierrez, Department of Anthropology

Thesis Committee Members
Douglas Bamforth, Department of Anthropology and Honors Council Representative
J. McKim Malville, Department of Astrophysical, Planetary, and Atmospheric Sciences

University of Colorado Boulder

April 2015

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

The completion of this thesis would not have been possible without the help of my research and personal support systems. Primarily, I want to thank my thesis advisor, Gerardo Gutierrez, for his excellent insight, significant patience, and availability while I was writing. Throughout this process, he has been essential in providing sources and direction. J. McKim Malville, has also given me numerous sources for my thesis as well and brought valuable outside perspective to the research. In addition, Douglas Bamforth deserves enormous amounts of gratitude for his crucial role in shepherding all the Anthropology Department honors students, myself included, to the finish line of our theses. Further, the statistical analyses completed in this thesis would not have been as complete without the help of Paul Sandberg. I am grateful for all of these professors' help on my thesis. Finally, I would like to thank my friends, family, and boyfriend for supporting me and allowing me to ramble endlessly about my thesis, even when they had no idea what I was saying.

ABSTRACT

Geographic Information Systems (GIS) and remote sensing, archaeology, and ethnohistory are used to study the Cuzco to Vilcashuaman portion of the Chinchaysuyu Inka Road. The purpose of this analysis is to determine whether the Chinchaysuyu road from Cuzco to Vilcashuaman was built following the economic principles of Least Cost Path Analysis (LCA) or if it was built to accommodate locations of cultural significance. Drawing on the criteria presented by Rademaker *et al*. 2012; White (2012); and Howey (2007), I created several LCAs in order to find the most predictive Least Cost Path (LCP). Research has led me to believe that the location of Inka roads was influenced by factors that cannot be well modeled by a LCA constrained to solely the ecological factors of the environment because of cultural and historical particularities associated with the construction of the Inka road system according to the need of the imperial hegemonic administration. By researching this road, I wish to examine the larger role of the Inka road system as a communication infrastructure vital to maintaining and expanding the imperial hegemonic administration of the Inka Empire over a vast track of the Andes. Ultimately, I hope the multivariate LCAs I created in this thesis will further the assessment of LCA as a suitable method of locating ancient routes.

1. *INTRODUCTION*

In this thesis, I use Geographic Information Systems (GIS) and remote sensing, archaeology, and ethnohistory to study the Cuzco to Vilcashuaman portion of the Chinchaysuyu Inka Road. Chinchaysuyu, the northwestern and most populous quarter of the Inka Empire, was composed of the first territories to be absorbed by the early Inka Empire It was essential to maintaining Inka imperial hegemonic administration of the Andes region. The Cuzco to Vilcashuaman portion of the road system is well-suited for this research because it not only is well-preserved, but it also is well-documented through the accounts of the early Spanish explorers and previous archaeological research (Betanzos 1996; Cobo 1979, 1990; Sarmiento de Gamboa 1907, 2007; Cieza de León 1967; Murúa 1986; Julien 2012). By researching this road, I was able to examine the larger role of the Inka road system as a communication infrastructure vital to maintaining and expanding the imperial hegemonic administration of the Inka Empire over a vast track of the Andes.

The purpose of this analysis is to determine whether the Chinchaysuyu road from Cuzco to Vilcashuaman was built following the economic principles of Least Cost Path Analysis (LCA) or if it was built to accommodate locations of cultural significance. Ultimately, I hope the multivariate LCAs I created in this thesis will further the assessment of LCA as a suitable method of locating ancient routes. Drawing on the criteria presented by Rademaker *et al*. 2012; White (2012); and Howey (2007), I performed several LCAs in order to find the most predictive Least Cost Path (LCP). I used the criteria of slope, distance from water, and caloric expenditure calculated with the Pandolf-Santee equations in varying combinations for a total of seven LCAs that were compared to the physical location of the road. I chose the criteria listed above because they provide a complete representation of the physical difficulties of traveling in this region. These difficulties include steep elevation changes, staying adequately hydrated, and the physical toll of traversing the landscape. Vegetation cover was a possible variable to add to this analysis, but I excluded it as the Chinchaysuyu road, like all large Inka roads, was paved. I hypothesize that the location of Inka roads was influenced by factors that cannot be well modeled by a LCA constrained to solely the ecological factors of the environment because of cultural and historical particularities associated with the construction of the Inka road system according to the needs of imperial hegemonic administration. As a result, I did not include distance from cities as a variable in any of the LCAs to limit the scope of the analysis to non-cultural factors and determine the likely effect of culture and history on the placement of the Cuzco to Vilcashuaman portion of the Chinchaysuyu road.

With this analysis, I seek to examine the economic principles of least effort used in LCA and assess whether this heuristic device is a satisfactory tool for predicting the paths of ancient road systems. Eventually, I would like to expand this research at a later date to investigate other methods of using geospatial analysis to improve the LCA modeling. In order to best present the anthropological scope of the research at hand, I wrote this thesis in five chapters. The first is an introduction to pertinent theoretical perspectives on the archaeology of empires and a synopsis of the state of knowledge on the Inka road system. I then placed the road system within the context of Inka history and culture in the second chapter. The third chapter integrates research on this road system into similar archaeological research performed on the road systems of other ancient civilizations. I introduce geospatial analysis in the fourth chapter in order to place my own research within the framework of previously performed geospatial analysis in archaeology. The final chapter presents the experiments with LCA performed and examines its efficacy.

DEFINING EMPIRES

To better understand the Inka road system and the role it played in the formation of the Inka Empire, an understanding of the current state of empire archaeology must be established. The basic definition of an empire is a territorially expansive and incorporative state with a strong imperial capital; domination of a territory through political control of provinces and economic exchange between capital and provinces; and projection of economic, political, and cultural influence in an international context (figure 1.1). The sociopolitical entities incorporated into an empire usually maintain a degree of their autonomy. For example, these communities are allowed to self-define cultural identity and/or perform limited political and economic decision-making. However, there is a disagreement between scholars whether a definition of empire should emphasize geographic, economic, political, ideological or military aspects. Many researchers circumvent this argument by conceiving of various kinds of empires determined by their degree of political and/or economic control. Under this classification, empires range from weakly integrated to highly centralized (figure 1.2). Eisenstadt, Luttwak, and Mann are the best-known proponents of classifying empires in this way though they all utilize their own terms (Doyle 1986; Sinopoli 1994: 159-160; Smith 2001: 131-132).

Wallerstein's world systems perspective, originally used to research the development of the modern global economy, is often applied to the research of archaic empires and has resulted in two variations on the previous definition. The first variation attempts to broaden Wallerstein's work to accommodate the qualitative discontinuities between the modern and ancient world. Chase-Dunn and Hall fall into this camp and define a world system as "intersocietal networks in

Features	Examples
1 *The imperial capital:*	
Large, complex urban center	
Proclamations of imperial ideology	1 Militarism 2 Glorification of king or of state
2 *Domination of a territory:*	
Economic exchange between capital and provinces	1 Provincial goods found at capital 2 Imperial goods found in provinces
Political control of provinces	1 Military conquest 2 Construction of imperial infrastructure 3 Imposition of tribute or taxes 4 Reorganization of settlement systems 5 Imperial coopting of local elites
3 *Projection of influence in a larger international context:*	
Economic influence	1 Trade with extra-imperial regions
Political influence	1 Military engagement and activities along enemy borders 2 Centralization or militarization of extra-imperial polities
Cultural influence	1 Adoption of imperial gods or rituals by distant peoples 2 Emulation of imperial styles and traits by distant peoples

Figure 1.1: Features of Empires (Smith 2001)

Major author	Weakly integrated	Highly integrated
Eisenstadt	patrimonial	imperial-bureaucratic
Luttwak	hegemonic	territorial
Mann	empire of domination	territorial

Figure 1.2: Frameworks for Imperial Organization (Sinopoli 1994)

which interaction … is an important condition of the reproduction of the internal structures of the composite units". According to Chase-Dunn and Hall, this "interaction" between the core polity and peripherals is political, military, or economic and may or may not be exploitative of the peripheral polities. The second school of thought retains Wallerstein's focus on capital accumulation and defines empires as political mechanisms to collect capital from peripheral areas. Under this perspective, capital is not limited to bulk goods and may include any form of culturally defined wealth (Sinopoli 1994: 160; Smith 2001: 131-132).

Though empires are widely variable, most undergo three common stages: expansion, consolidation, and collapse. Territorial expansion is the essential process in the formation of the geographic and demographic entity that becomes an empire. Histories of imperial growth are closely tied to individual rulers. However, conquest histories are rarely linear; cycles of rebellion and reconquest are common which causes ambiguity in the archaeological record. The motives behind imperial expansion are even more difficult to ascertain than the history, however. When motivations are expressed it is usually post facto and used for legitimation. Doyle tackled the difficulty of ascertaining motives of imperial expansion and identified three loci of expansionist motives: metrocentric, pericentric, and systemic. According to Doyle's hypothesis, expansion is a response to conditions at the center, periphery, or in power differentials between the two. Specific motives include ideological factors, economic goals, or security concerns. The variability in motives explains the non-sequential pattern of imperial expansion: it is affected by local political conditions and distribution of resources. As a result, more distant areas with key resources or political significance are typically conquered prior to areas of little economic or strategic value (Sinopoli 1994: 162-163; Smith 2001: 130-131).

In order to maintain conquered lands, burgeoning empires must create a system of structural connections and dependencies among the regions and populations to consolidate them. To sustain consolidation of populations, empires must create new economic, military, and social institutions, administrative structures, and ideological systems. This also includes the disruption of previously autonomous local institutions. Eventually, all empires become unsustainable and collapse, whether for economic, political, or environmental reasons. Imperial collapse involves the dissolution of the centralized institutions developed during consolidation, but this dissolution does not result in total civilizational collapse. Institutions, social relations, and ideology may outlast empires and exist in localized patterns and often new empires rise out of the ideologies of previously collapsed polities (Schreiber 1987: 266-267; Sinopoli 1994: 163-169).

Imperial consolidation is the easiest stage of empires to identify in the archaeological record. Archaeological evidence of consolidation of subjugated regions can be found in the construction of imperial facilities and changes in local material culture. In order to understand more fully the process of empire formation, the requirements of the empire and local preexisting conditions must be examined (Schreiber 1987: 267). In the case of the Inka Empire and its imperial hegemonic administration of the Andes, the process of empire formation can be understood by researching the Inka road system. Built to consolidate the Empire, the road system was an expansive infrastructure that relied on four groups of specialized laborers, some of which were political migrants known as mitmaqkuna, and a labor tax known as mit'a in order to consolidate capital in Cuzco. The mitmaqkuna were used to break up unified ethnic identity in regions prone to rebelling against the empire. The mit'a further integrated conquered peoples into the empire and also used them to build the infrastructure, such as roads. For the Inka, the roads were inseparable from the means of creating and maintaining power (Besom 2013: 11-14, 211-212, 271, 275; Betanzos 1996: 104; Bruhns 1994: 391-392; Cobo 1979: 266, 268; Julien 1988: 272; Kolata 2012: 84-87, 104-105; MacCormack 1991: 459; Morris and Von Hagen 2011: 60; Silverblatt 1987: 229).

THE INKA ROAD SYSTEM

The Inka road system spreads from Ecuador to Argentina and is monumental in its scope (figure 1.3). The roads were used primarily for travelers on state business and range anywhere from broad, well-constructed roads to narrow paths with little or no evidence of formal construction. Some of these roads were not even originally Inka and were built prior to the Inka

Figure 1.3: Map of the Inka Road System (Hyslop 1984)

Empire and then integrated into the road system. The roads built by pre-Inka people and the Inka themselves follow the long-standing tradition of road-building in the Andes. Due to the extreme geography of the Andes roads were used to connect disparate ecological zones and create complementary economic relationships between large centers of population (Besom 2013: 11-14, 211-212, 271; Cobo 1979: 266; Hyslop 1984: xiii, 2-3; Kolata 2012: 104-105; Bruhns 1994: 391-392; Silverblatt 1987: 229).

Construction of the roads relied heavily on natural factors. The environmental conditions of the terrain and the material composition of land surface influenced the way Inka roads were built. When constructing a road, two types of slopes must be dealt with: vertical and horizontal. When faced with vertical slopes, the Inka would use one of three methods to construct roads. The first, is to smooth the road into a ramp-like structure and was performed on roads with a slope of 10˚ or less. When slopes exceeded 10˚, they would either construct steps made of large fieldstones into the road or create a zigzag path up or down the face of the slope. Horizontal slopes were accommodated through the creation of retention walls to stabilize the road. Local construction materials were extracted from nearby surroundings and resulted in highly variability for road construction. The roads could be unmarked footpaths or roads marked by stone piles, rows of stones, wooden stakes, or sidewalls of stones, adobe, or tapia (Hyslop 1984: 225-244).

The Inka expanded on the practicality of roads and utilized them as a complex administrative, transport, and communication system inextricable from their ideology. The roads were essential to the maintenance of imperial hegemonic administration of the Andes. Roads described state geography of the Empire, dividing the realm into four quarters by main roads leading out from Cuzco. Every population and locale in the Inka Empire was described in relation to their position on the road. Through tributary obligations of conquered populations, the road system was built and maintained. To subject populations of the Empire, the roads were an omnipresent symbol of the empire. Symbolically, the road system expressed the cultural geography of the empire. Using the ideology of the ceque system, the Inka connected the roads to conceptual divisions of society and space. The roads were imbued with the same animism with which the Inka viewed their entire environment (Bauer 1998; Cobo 1990: 51-84; D’Altroy 2015: 263-264; Hyslop 1984: xiii; Kolata 2012: 146, 158).

Documentary Sources of the Inka Roads

The first descriptions on the Inka road system come from members of the invading Spanish force that captured and killed Atahualpa at Cajamarca and then seized Cuzco, including Hernando Pizarro, Francisco de Xerez, Pedro Sancho, Miguel de Estete, Cristobal de Mena, and Juan Ruiz de Arce (D'Altroy 2015: 18-19; Rowe 1946: 194-5). Pedro de Cieza de Leon, a later Spanish explorer, wrote one of the most detailed accounts on the roads. From 1547 to 1550, he traveled through the northern half of the realm, making observations about the climate, settlement patterns, locals' daily life, and myths. While in Cuzco, Cieza de Leon interviewed aristocrats about their history and government. He admired the Inka's achievements, particularly the roads (1967: 213 - 14; translation from Hyslop 1984: 343; D'Altroy 2015: 4, 19; Rowe 1946: 195):

> "In human memory, I believe that there is no account of a road as great as this, running through deep valleys, high mountains, banks of snow, torrents of water, living rock, and wild rivers ... In all places it was clean and swept free of refuse, with lodgings, storehouses, Sun temples, and posts along the route. Oh! Can anything similar be claimed for Alexander or any of the powerful kings who ruled the world?"

Cieza de Leon's texts were the first to report the total length of the Chinchaysuyu road from Cuzco to Quito, a length of 1100 leagues (1553: 45; Hyslop 1984: 215). The league, the measurement most commonly used by Spanish explorers, is of variable length. However, it is believed that 1100 leagues converts to about 5500 kilometers. This distance has proved to be a relatively accurate measurement and provides a general idea of the length of one of the four main roads as well as a general idea of the size of the Empire. Garcilaso de la Vega also wrote on this road, though he primarily quoted other historians for his account. He reports the length of the path of the road from Cuzco to Quito as 500 leagues, an uncorroborated figure (Enock 1908: 25). Other explorers such as Vaca de Castro (1543) and Guaman Poma de Ayala (1614) expanded the view of the road system by listing the tampus they encountered as they traveled the Inka roads. This is not a perfect representation of the road system at the height of the Inka Empire as it covers only the roads utilized by Spanish colonial administration. As a result, side routes and bifurcations or trifurcations of main routes were ignored. In addition, Guaman Poma de Ayala does not mention the roads of Chile and Argentina while including roads of Colombia, which were not a part of the Empire. Vaca de Castro's list is even more limited listing only the roads in Peru, Bolivia, and parts of Ecuador (Hyslop 1984: 215-216).

In 1557, Damián de Bandera reported on the former Inka province of Vilcashuaman to the Viceroy Andrés Hurtado de Mendoza. He generally described the scope and attributes of the province, however, his report is of interest as it was oriented using the Chinchaysuyu Road that runs from Cuzco all the way to Quito. His work also provides valuable insights on tribute, decimal administration, succession of local nobility, property inheritance, the administration of justice, and labor performed for the Inka (Bandera 1557; Zuidema 2008: 71). Juan Diez de Betanzos recorded the history of the construction of the road stretching through this province form Cuzco as part of the conquests of the Chanka by Pachakuti. According to Betanzos, the Chinchaysuyu road was constructed as the army progressed and on the trek back to Cuzco with captives. During this campaign, the suspension bridges crossing the Apurimac and Pampas rivers were erected (Bauer 2006, Betanzos 1996: 26, Julien 2012: 149-151).

Through most of the seventeenth and eighteenth centuries, the Inka road system went uninvestigated until the Prussian explorer Alexander von Humboldt traveled to South America in 1814. His account of the roads was probably inspired by that of Cieza de Leon. He was impressed by the precision and accuracy of all Inkan architecture, particularly the road system (Dettelbach 2008: 307). According to von Humboldt "The great road of the lnka was one of the most useful, and at the same time, most gigantic works ever executed by man" (Humboldt 1814). His comments renewed interest in the Inka roads by the first Andean archaeologists in the nineteenth century (Hyslop 1984: 216). In contrast, the twentieth century explorer Charles Reginald Enock was less than impressed by the roads. In 1908, he published the accounts of his travels in Peru, particularly from Cuzco to Quito, and reported that "[the Inka roads] importance as engineering works has been much exaggerated" (Enock 1908: 25). His account lacks detail and is mostly derived from Garcilaso de la Vega.

The Archaeological Investigation of the Inka Roads

These first Andean archaeologists were more of adventurers than scientists and included men such as Ephraim George Squier, Charles Weiner, and Antonio Raimondi. Their work described and mapped many Inka settlements along the main road system, in particular the royal family estates in the Urubamba Valley, but did not attempt to understand the system's dimensions (D'Altroy 2015: 27; Hyslop 1984: 216; Moseley 2001: 18-19). In 1869, William H. Prescott attempted to define the entire road system using early ethnohistorical sources. However, his interpretation of the road was extremely simplified and incorrectly reported the road from Cuzco to Quito to be about 3200 kilometers. He most likely used a definition of a league that was longer than the one used by Spanish explorers, leading him to argue that the road in question was 2400 kilometers shorter than it actually was (Hyslop 1984: 216). In quick succession, researchers such as Raimondi and Charles Wiener published detailed and accurate descriptions and maps of the road system using similar sources and methods to Prescott. Raimondi focused on the Quito to Lake Titicaca region and Wiener described Peru and Bolivia. Around this time, Clements R. Markham created a map from historical sources that represented the routes the journeys embarked on by Inka emperors (Hyslop 1984: 216-217)

Maps depicting only the main arteries of the Inka road system from historical sources continued into the 1930's with the work of Horacio H. Urteaga and Alberto Regal. Urteaga's map was ill-researched but well-distributed, while Regal's was impeccably researched and underappreciated. Neither of these maps relied on field research, and the maps that followed their work reported only short segments of the road that were described in the field. Resurgence in mapping the entirety of the road system occurred between the 1940's and 1960's. These maps include the efforts of Robert Levillier, Victor Von Hagen, Dorothy Menzel, Hans D. Disselhoff, Juan Schobinger, and Leon Strube Erdmann. Out of all these representations, Erdmann's was the most expansive and accurate, but almost all of them lack strength in their representations of the Inka road system outside of Peru (Hyslop 1984: 216-218).

From the 1960's to 1980's, maps of the road system became more regional and a synthesis of the entire road system was not attempted until John Hyslop's *The Inka Road System* in 1984. Hyslop surveyed numerous segments of the road system from Ecuador all the way to the Atacama Desert. He sought out survey locations that provided environmental diversity, local late prehistoric cultural diversity, variability of lnka rule, main arteries and secondary routes, and geographical dispersion (Hyslop 1984: 6). He paired his field research with historical sources and past archaeological research. As a result, he created an overview of the Inka Empire unparalleled in its breadth. Satellite imagery and geospatial analysis are promising new methods to research the large-scale patterns of the Inka road system. At the very least, satellite imagery allows for detailed maps and geospatial analysis is used to further a comprehensive representation of the road system in its entirety (Julien 2012, figure 1.4). In 2001, David Jenkins expanded on Hyslop's work by performing a network analysis of the Inka roads, administrative centers, and storage facilities. He concluded network models are useful in explaining the patterns

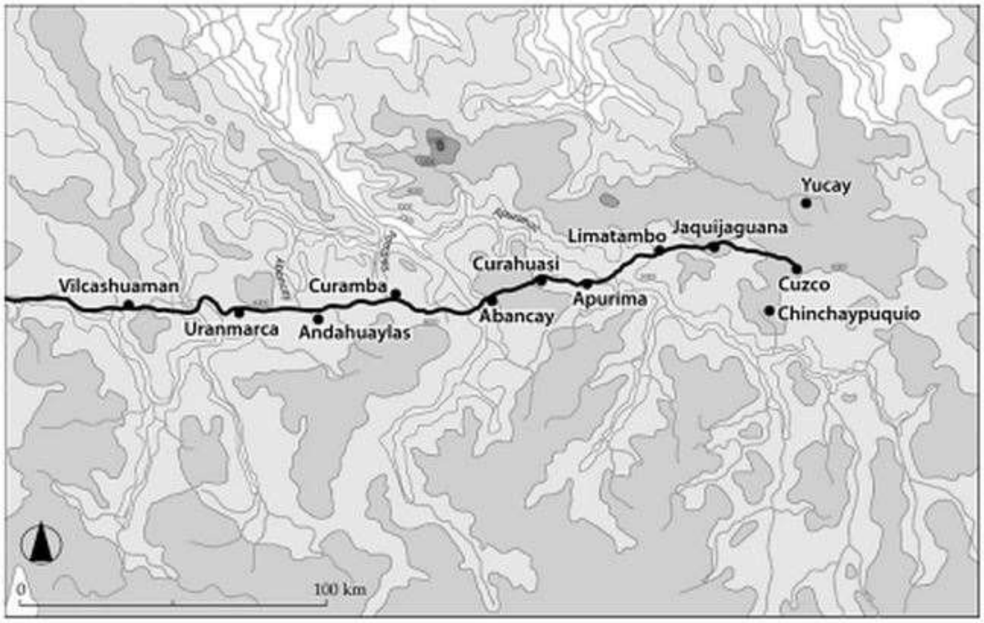


Figure 1.4: Chinchaysuyu Road from Cuzco to Vilcashuaman (Julien 2012)

and relationships of the administrative centers, storehouses, and roads of the Inka Empire. Hopefully his research and other similar work will propel more research into the Inka road system, which is still not wholly mapped or understood.

2. INKA HISTORY AND CULTURE

Without an understanding of the history and culture of the Inka, the geospatial analysis presented in this thesis would be incomplete. The roads of the Inka Empire were inextricable from the Inka's imperialistic expansion. As a result, the roads were imbued with all the social, political, economic, and religious traditions that the Inka spread throughout the Andes. It could be said that the Inka road system was a physical representation of the permeation of Inka ideology throughout their Empire.

ORIGINS OF THE INKA

Mythical Interpretation

The Inka Empire, or Tawantisuyu (The Land of the Four Quarters), quickly spread as a regional power in the Andes during the fifteenth century, but little is known today of the pre-imperial history of the Inka. Two mythical narratives summarized the origins and rise to regional power of their Empire: the myth of the Ayar siblings and the Chanka Wars that led to the ascension of the emperor Pachakuti. The tale of the Ayar siblings is best recorded in the writings of Sarmiento de Gamboa, a Spanish chronicler who wrote his account of the myth after interviewing over 100 Cuzco khipukamayuqs (creators and curators of khipus). The tale details the events leading up to the founding of Cuzco by the original member of the official Inka dynasty, named Ayar Manco but later referred to as Manco Qhapaq, and his three brothers and four sisters. Manco Qhapaq and his siblings were summoned by the creator god Wiraqocha from the central cave, Qhapaq T'oqo, from a cave system called Tampu T'oqo near a possibly fictional location known as Pacariqtambo (inn of dawn). Several locations have been suggested for the actual location of Tampu T'oqo. Hiram Bingham proposed Machu Picchu; Luis Pardo argued for Maucallacta; and McEwan, Gibaja, and Chatfield advocated Chokepukio (Hiltunen and McEwan 2004: 240). The ancestors of the Tambo and Maras ethnic groups emerged from adjoining caves, Mara T'oqo and Sutiq T'oqo, and accompanied the siblings in search of land to claim as their own (D'Altroy 2015: 70-72; Hiltunen and McEwan 2004: 238; Moseley 2001: 15; Sarmiento de Gamboa 2007: 60; Morris and Von Hagen 2011: 25).

During the siblings' journey, one of the brothers, Ayar Kachi was unruly, smashing mountains into ravines and "making war on all those who do not receive [the siblings] as their lords" (D'Altroy 2015: 72; Sarmiento de Gamboa 1907: 45; Sarmiento de Gamboa 2007: 65; Morris and Von Hagen 2011: 25). The siblings claimed they had forgotten golden vessels, seeds, and other necessities in the origin cave and tricked Ayar Kachi into reentering Qhapaq T'oqo where he was entombed and turned to stone. Another brother, Ayar Uchu, was later transformed into a stone pillar on the summit of Wanakawri, which is now one of Cuzco's most sacred shrines (D'Altroy 2015: 72; Rowe 1946: 296; Morris and Von Hagen 2011: 25). At Matagua, Manco Qhapaq or his sister Mama Waku cast two golden staffs into the valley. The first did not stick firmly in the soil, and the siblings knew the land was not fertile. The second plunged deep into the earth at Wanaypata, and the Inkas knew this location would be their land. The brother Ayar Awka flew to the site where the Qorikancha, the sun temple, would be built and transformed himself into a stone pillar to serve as a boundary marker or "stone of possession". Here, the remaining four sisters, Manco Qhapaq, his son Zinchi Roq'a, and the Tambo and Maras ayllus (large kinship groups) settled and founded Cuzco; "in the ancient language of this valley the heap was called eozeo, whence that site has had the name of Cuzco to this day" (D'Altroy 2015: 72-73; Sarmiento de Gamboa 1907: 55; Morris and Von Hagen 2011: 25). The settlers displaced the previous inhabitants, the Guayllas, who had called their village Acamama. Presently, the exploits of Cuzco's mythical founders are enshrined in Cuzco's ceque system, lines of shrines that defined the city's ritual and economic organization (D'Altroy 2015: 72-74; Moseley 2001: 15; Sarmiento de Gamboa 2007: 69; Morris and Von Hagen 2011: 25-26). Another version of the Inka origins that gets conflated with the one described above states that the deity Wiraqocha created the Inka people on the Island of the Sun in the Lake Titicaca. The Inka then migrated north to Cuzco and defeated local ethnic groups. This account is not well-documented but does resonate with the Tiwanaku influences seen in Inkan statecraft (D'Altroy 2015: 84; Hiltunen and McEwan 2004: 239).

The most common myth to explain the Inkas sudden rise to regional dominance details the heroic feats of Pachakuti, the ninth king in the king list, in the Chanka wars. The Chankas were an Andean ethnic group, descended from the Wari, centered west of Cuzco in Andahuaylas from 1100 to 1400. They lived in high altitude villages surrounded by walls up to 2 meters high or defensive ditches. Recent archaeological surveys of Andahualyas suggest that the Chankas lacked cohesion and were not powerful, although they may have formed a loose confederation to contest Inka expansion. The Inkas may have perceived the Chankas as obstacles to their burgeoning empire as the Chankas were located along the Apurimac and Pampas Rivers, restricted access to coastal goods and the road to Chinchaysuyu. During the height of the Inka Empire, famous rope bridges were built spanning these rivers to facilitate travel from Cuzco to Chinchaysuyu, one of the quarters of the empire, so access to these rivers was essential for the Inka to expand their territory (Bauer *et al*. 2010; D'Altroy 2015: 94; Kellett 2010; Morris and Von Hagen 2011: 26). Conversely, the Chankas may have intended to regain a foothold in Cuzco, which had been previously occupied by the Wari (Moseley 2001: 13; Morris and Von Hagen 2011: 26).

According to legend, during the reign of the eighth king Wiraqocha, the Chankas sent messengers to Cuzco demanding the ruler's surrender. Wiraqocha abandoned the city with his designated heir, Inka Urco leaving his other son, Inka Yupanki, to defend the city from the aggressing Chankas. Inka Yupanki called on the surrounding ayllus to help in defending Cuzco, rallying three lords (D'Altroy 2015: 93). Soon after, Inka Yupanki received a vision of Inti (the Inka sun or creator god) while at a spring. Inti informed Inka Yupanki that he would be "greater than any of his ancestors . . . because he would conquer the Chankas who were marching on Cuzco" (Sarmiento de Gamboa 1907: 91; Morris and Von Hagen 2011: 26). As the Chankas reached the northern outskirts of the city, the stones in the fields transformed into twenty squadrons of soldiers called pururaucas. With the pururaucas, Inka Yupanki turned away the Chankas' troops and pursued them west of Cuzco to the plain of Anta. About a dozen of these pururaucas became enshrined in Cuzco's ceque system. After his victory, Inka Yupanki presented the prisoners and spoils of war to his father. The father refused to treat him with respect and insisted that Inka Urco should take credit for defeat of the Chankas. Insulted, Inka Yupanki withdrew his offering and returned to Cuzco as de facto ruler; some say he staged a coup and had Inka Urco murdered. After regrouping, the Chankas renewed their attack on Cuzco. Inka Yupanki engaged the Chankas in a site now known as Yawarpampa or "field of blood". The Chankas fled the battle, many drowning in the Apurimac River. From this time onward, Inka Yupanki was known as Pachakuti, "transformer of the world". He founded the dynasty of the Inka Empire and began the Inka expansion (figure 2.1). After expanding into the Chanka territory, the Inka relocated almost all inhabitants as mitmaqkuna and replaced them with loyal mitmaqkuna (D'Altroy 2015: 93-94, 273, 276; Diez de Betanzos 1996: 19-30; Cobo 1979:

128-9; MacCormack 1991: 286-301; Moseley 2001: 15; Pachacuti Yamqui 1993: 219; Polo 1917: 46; Morris and Von Hagen 2011: 26-28).

After defeating the Chanka, Pachakuti continued to spread his empire with the aid of his sons Qhapaq Yupanki and Thupa Inka. Using forces from the conquered Chanka population, Pachakuti led a conquest into the southern expanses of the eventual Inka Empire, throughout Peru and then into Ecuador. In the south, the Inka conquered the Qollas, Lupaqa, and Ayaviris. Pachakuti fought through Bolivia before heading northward (D'Altroy 2015: 96; Diez de Betanzos 1996: 112-14). The conquests though Peru led to the rife among the Chanka and the Inka forces. The Chanka abandoned the conquest, however, the Chincha and Pisco Valleys were peacefully brought into the Inka Empire and the Chimu Empire fell either during the conquest or during the conquest into Ecuador (Castro and Ortega Morejón 1974: 94-103, D'Altroy 2015: 96-104; Canseco 1999: 71, 78; Rowe 1948: 44).

	Name as ruler	*Gloss*	*Given name*
1	Manqo Qhapaq	Powerful [Ancestor]	–
2	Zinchi Roq'a	Warlord Roq'a	–
3	Lloq'e Yupanki	Honored Left-handed	–
4	Mayta Qhapaq	Royal Mayta	–
5	Qhapaq Yupanki	Powerful Honored	–
6	Inka Roq'a	Inka Roq'a	–
7	Yawar Waqaq	He Who Cries Bloody Tears	Inka Yupanki, Mayta Yupanki
8	Wiraqocha Inka	Creator God Inca	Hatun Thupa Inka
9	Pachakuti Inka Yupanki	Cataclysm Honored Inca	Inka Yupanki, Kusi Yupanki
10	Thupa Inka Yupanki	Royal Honored Inca	–
11	Wayna Qhapaq	Powerful Youth	Titu Kusi Wallpa
12	Waskhar Inka	Golden Chain Ruler	Thupa Kusi Wallpa
13	Atawallpa	–	–

Figure 2.1: Inka King List (D'Altroy 2015)

The epic nature of the history of Pachakuti suggests that the Inkas may have invented this history to glorify Pachakuti, as many conquests attributed to him, like the defeat of the Qolla and Lupaqa lords in the altiplano, the conquering of the Lunahuaná and Mara people, and the expansion of the Inka Empire along the coast from Nazca to Mala, were probably undertaken by his son Thupa Inka Yupanki (D'Altroy 2015: 96-104; Duviols 1980; Morris and Von Hagen 2011: 27). There is a consensus that Thupa Inka Yupanki expanded the empire into Chile and Argentina and that the Inka Empire was not truly consolidated until Wayna Qhapaq, though. Under Wayna Qhapaq's rule, the empire grew to its eventual size (D'Altroy 2015: 104). Successive emperors maintained the Empire until the Spanish Conquest (figure 2.2).

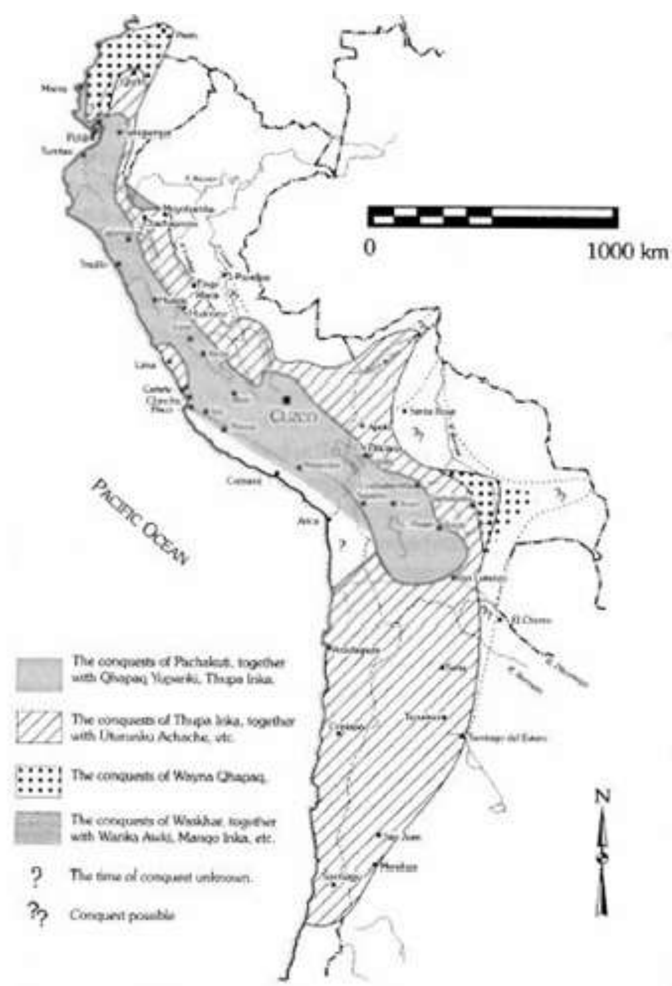


Figure 2.2: Map of the Inka Conquests (D'Altroy 2015)

Historical and Archaeological Interpretation

When it comes to non-mythical interpretations of the history of the Inka, information becomes scarcer. Rowe (1944: 57) recommends the use of the last part of a chronology proposed by the cleric Miguel de Cabello Valboa (1951) in 1586 as the most plausible to be found in the chronicles. Most authors follow this recommendation, and as a result the consensus is that the imperial era of the Inka began around AD 1438 when the Inka repelled an attack by the Chankas and lasted about a century. Cabello reports the imperial successions occurred at 1471, 1493, and 1526. Cabello's pre-imperial succession dates, however, are considered unlikely. Though his sources remain unknown, Cabello's dates were supported indirectly by corroborating with other chroniclers' accounts and the accordance of Cuzco accounts, with few discrepancies, of conquest sequences with provincial accounts (D'Altroy 2015: 63; Pärssinen 1992). Other scholars reject Spanish accounts as a viable source for dates as they produce at least four chronological sequences other than Cabello's and yield unbelievable dates. It is not credible, for example, that numerous rulers lived to be well over 100 (D'Altroy 2015: 63; Covey 2006). A large part of this confusion is the absence of a decipherable Inka record system but also the Inka's conception of the past. The Inka tracked annual cycles with great precision, but accumulating years were not closely traced (D'Altroy 2015: 63; Rowe 1946: 274). Cobo (1979: 252-3) presented the Inka's perception of the past in this way:

> "When they are asked about things of the past, if something happened more than four to six years back, what they usually answer is that the incident occurred *ñaupapacha*, which means "a long time ago"; and they give the same answer for events of twenty years back as for events of a hundred or a thousand years back, except that when the thing is very ancient, they express this by a certain accent and ponderation of their words."

This perception of time undoubtedly complicates the task of describing the Inka's historical trajectory prior to the arrival of the Spanish, but has not made it impossible. Several interpretations of the Inka's pre-imperial history have arisen. One archaeological interpretation, based on radiocarbon dates and Inka material culture, proposes the Inka developed into a well-defined cultural group by the early 11th century. They rapidly expanded into an empire after C.E. 1400, a few decades after Cabello's historical chronology reported, as a result of long-term processes of state formation and regional consolidation. However, this chronology has its own weaknesses, namely whether radiocarbon dates are accurate enough to use within such a small time frame (Adamska and Michecynski 1996; Bauer 1992; Bauer and Covey 2004; Covey 2006; D'Altroy 2015: 64, 85). Scholars do agree the Lake Titicaca Basin is indispensable to the Inkan identity: the mytho-history, style of stone-carving, and political organization are all similar to the altiplano. Using matrilineal DNA from over a one hundred Inka-era skeletal remains from the Cuzco and Machu Picchu areas and comparing with ancient remains from other sites throughout the Andes, Shinoda and his colleagues confirmed the Inka's ties with the Lake Titicaca region. Further, these researchers found individuals sharing in the Inka matrilineal gene pool did not appear in the Cuzco region until shortly after AD 1000 (D'Altroy 2015: 84-85; Shinoda *et al*. 2006).

After AD 1000, the Inkas developed from a hierarchical society to a centralized state in the Cuzco Valley and extended administrative control over neighboring groups over the course of the next 300-400 years (Bauer and Covey 2002: 851; D'Altroy 2015: 85-86). Less powerful polities accepted Inka administration early on and possibly initiated patronage relationships with the Empire. Strong rivals to the Inka Empire maintained their independence, at times depopulating intermediate areas and settling in defensive sites to protect settlements and resources. The Pinagua and Muyna, east of the Cuzco Valley in the Lucre Basin were strong rivals to Inka rule and the depopulation of the land between the Cuzco and Lucre Basins illustrates the establishment of a buffer zone between two rival polities along the Vilcanota Valley. The king Inka Roq'a eventually conquered these groups, solidifying Inka control of the linked Cuzco-Vilcanota Valleys drainages (Bauer and Covey 2002: 858-859; Cieza de Leon 1967: 115-22; D'Altroy 2015: 75; Murúa 1986: 69). Other groups were sometimes brought into alliance with the Inka through strategic noble marriages; examples of marriage alliances were seen among the Huayllacan, Anta, and Ayarmaca (Bauer and Covey 2002: 858-859; D'Altroy 2015: 75, 86; Morris and Von Hagen 2011: 45). Groups of intermediate complexity used alliances and violence to align themselves with the strongest regional competitors, such as the alliance made between Huaro and the Inka site of Ollantaytambo, despite Huaro's proximity to Pingua and Ayarmaca (Bauer and Covey 2002: 858-859).

Warfare and strategic alliances does not wholly explain why the Inka were so successful at expansion. By the time the Inka state began to form, conflicts and alliances of the peoples of southern Peru and the northern altiplano had been present for centuries. Narratives suggest that this climate placed a premium on capable military leaders and there were significant benefits to predatory warfare and alliances. War would have increasingly concentrated power in the hands of a few families throughout the years. Another explanation for Inkan expansionism relies on the religious beliefs, where the creator god Wiraqocha exhorted the Inka to civilize other groups, a feature ever present in late imperial ideology. However, these exhortations may simply be post facto justifications, rather than catalysts for expansion (D'Altroy 2015: 86; Bauer and Covey 2002: 861; Bauer and Covey 2004).

INKA CULTURE

Social Order

Elites. The most elite classes in the Inka Empire consisted of the Inkas and their closest subjects. These classes included the royal family, panaqas (descendent kin) of past rulers, non-royal ethnic Inkas, and the Inkas by privilege. Nobles occupied diverse roles in the Inka Empire, from decimal administration officials to military and civic leaders. There was even a taxonomy of nobility, where a noble's status could be distinguished by their lineage, military stature, civic role, or source of wealth. Labels even existed for commoners raised into the elite class, usually through performance in war, and for individuals who simply played the role of having power or had usurped power. Further, all variations of nobility were distinguished from the kamayuq, occupational specialists found among the commoners (D'Altroy 2015: 293; Kolata 2012: 58-80; Morris and Von Hagen 2011: 22, 30).

Peasants. The majority of the Inka population, 95 to 98 percent, were peasants and lived in towns and villages as farmers, herders, fishers, and artisans. The average llaqta (highland community) of the central Andes was composed of one or more ayllus, a self-governing form of social organization of kinship groups that existed prior to the Inka. The largest of these ayllus could contain up to several lineages and hundreds of households. The lineages of the ayllus could hold statuses of different social ranks. The ayllus and its member households were often widespread in order to benefit from several ecological zones and be self-reliant for quotidian needs. The impact of the Inka occupation on ayllus mostly involved a shift from villages located on high-elevation peaks to dispersed communities near the valley bottoms. Further, prior to the Inka, the villages contained no monumental, public architecture. The largest communities had, at most, centrally organized public spaces between two residential sectors for feasting (D'Altroy 2015: 293-295; Kolata 2012: 49-58; Morris and Von Hagen 2011: 35-36).

Specialized Labor Classes. Separate from the noble and peasant classes were the specialized labor classes of the Inka. The Empire instituted a system of specialized labor to provide the Inka nobility with servants and elite goods, and suppressed any possible rebellion among conquered peoples. Spanish administrators during the first decades of Spanish rule, such as Juan Polo de Ondegardo, repeatedly wrote on these forms of specialized labor and noted that these individuals, with a few exceptions, were excused from other tributary obligations (Polo de Ondegardo 1917). Four types of specialized labor were observed among the subjugated peoples within the Inka Empire: yanakuna, aqllakuna and mamakuna, kamayuqkuna, and mitmaqkuna. The first category of specialized labor, the yanakuna, yana singular, is similar to that of a personal retainer. They were attached to the households of Inka lords or to temples and shrines. The position of yanakuna was inheritable and their duties ranged from domestic servitude to minor officials with limited administrative power. The yanakuna were able to ascend through the social hierarchy, accounting for this wide range of responsibilities (Besom 2013: 275; Betanzos 1996: 104; Cobo 1979: 268; Julien 1988: 272; Kolata 2012: 84-87; MacCormack 1991: 459; Morris and Von Hagen 2011: 60). Kamayuqkuna (kamayuq) were similar to the yanakuna in that they labored on behalf of an Inka lord and their status was also inheritable. They were master craftsmen of all types. They mined precious metals; created fine textiles, pottery, and sandals; were carpenters and stone masons; porters and bodyguards; herbalists; accountants; hunters and honey-gatherers; and many other types of specialized production. One of their most important roles was the creating and maintaining of the Inka imperial records, or khipu. A kamayuq relegated to this profession was known as a khipukamayuq (DeLeonardis 2011: 446-450; Hayashida 1999: 338; Kolata 2012: 87-92; Morris and Von Hagen 2011: 64).

Certain forms of specialized labor and retainers were solely female-dominated and known as the aqllakuna and mamakuna, or “chosen women”. These women either served the state cults, the royal family and individuals favored by the king, or were charged with the production of chicha, a traditional corn beer. Occasionally they also created ceremonial textiles (Hayashida 2008: 172; Kolata 2012: 92-96). These women were chosen at a young age, about eight to ten years old, and were reported to be of great beauty. At times they were sacrificed to ensure the continued prosperity of a noble household or were offered as brides in strategic noble marriages (Besom 2013: 8, 268; Cobo 1990: 261; Holguín 1952: 15; Kolata 2012: 92-96; Morris Von Hagen 2011: 46, 60; Rowe 1946: 269; Silverblatt 1987: 227).

The final type of labor service were the mitmaqkuna of which there were three types: military, political, and economic. The role of a military mitmaq is self-explanatory, conscripted soldiers from the non-Inka population used to enforce the rule of the Inka throughout the Andes. Political mitmaqkuna were transplanted colonists who had been forcibly removed from their homes and legally required to maintain all traditions, social organization, and manners of dress of their ethnicity. The purpose of transplanting portions of non-Inka populations and forcing them to preserve their customs reduced the chances of rebellion in conquered provinces by fragmenting shared ethnic identity among large contiguous populations. Upon resettling, political mitmaqkuna were expected to contribute to the tributary tax of their new province. Economic mitmaqkuna were also transplanted, but they were used to strengthen Inka claim to marginalized lands. They were provided land, women, textiles, and state support in their endeavors to reincorporate lands into the Empire. Once they were successfully established, they were required to pay tributary tax (Besom 2013: 8-14; Kolata 2012: 80-84; Morris and Von Hagen 2011: 60).

Political Order

To facilitate their rule of the Andean region, the Inka imposed a decimal administration system to organize census taking and tributary obligations. Little is known about this organization outside of what is presented in traditional historical sources, which often do not provide much detail. Accounts of Spanish chroniclers provide a consensus that the decimal administration organized the provinces of the Empire via a nested hierarchy of decimal units ranging from one family to ten thousand and was used for census taking and the organization of tax collection (Castro and Ortega Morejón 1974: 98; Cieza de Leon 1967; Cobo 1979; Polo de Ondegardo 1917). However, these sources present decimal administration as a rigid organization, belying the actual complexity of incorporating the politically heterogeneous population of the Andes into the single political body of the Inka Empire (Julien 1988: 257-258; Kolata 2012: 233-235). Further, the exact processes by which the Inka Empire absorbed non-Inka political organizations into their system of decimal administration remain unclear.

For most of the history of Inkan research, Murra's hypothesis of the "vertical archipelago" has been accepted as the best explanation for the incorporation of non-Inkan entities into the Inka Empire. Murra proposes that the Inka reoriented existing governments of conquered people to meet their own demands (Julien 1988: 260; Morris and Thompson 1985: 483; Murra 1984: 65-67; Pease 1978: 64). Julien challenges this hypothesis by suggesting that at times Inka imposed bureaucratic order of their own design and at others reoriented existing political organizations. As a result, Inka decimal administration relied on local political authority while at the same time metamorphosing it into a standardized system of provincial authority. To support her hypothesis, she discusses the opposing methods of the implementation of decimal administration used on the Qolla and Chachapoyas. The Qolla polity of the Lake Titicaca region were divided into smaller provinces upon their absorption into the Inka due to their large size (Julien 1983: 216-220).

Conversely, Chachapoyas in far northeastern Peru was originally a constellation of small polities that were organized into one province under Inka rule. During the short span of time the Inka ruled Chachapoyas prior to the Spanish Conquest, five different men were assigned as provincial administrator. Two of these men were of local prominence, supporting the argument of the Inka adopting existing political organization for their own means. However, at least two of the remaining administrators were granted this position through their service to the Inka state. One had been a hereditary retainer, yana, and the other was the leader of the group assigned to maize cultivation in fulfillment of the labor tax, mit'a. Much more is known of the Inka role in the shaping of local authority in Chachapoyas than of the Qolla, but Julien argues the heavy involvement of the Inka in shaping local authority in Chachapoyas illustrates that the relationship developed between Cuzco and the local population is more important in determining the degree of formal change to local political authority than the distance from Cuzco or the length of incorporation (Cabello Valboa 1951: 399-400; Espinoza Soriano 1969: 294, 305-6, 312; Julien 1988: 271-272).

Despite the disagreements as to how decimal administration standardized the varying political identities of the Andes, there is agreement in the literature that decimal administration allowed for the extraction of tributary tax from conquered peoples (Besom 2013: 9, 211; Julien 1988: 274; Kolata: 2012, 144-145). This tributary tax was known as the mit'a and was exacted through labor. The mit'a system, allowed the Inka to fortify their control not only through claims to their subjects' labor but by also the use of that labor for the creation of state infrastructure. Through the fulfillment of the mit'a labor tax armies were populated; agricultural fields tended to; and bridges and oroyas, roads, tampus, storehouses, and administration centers were built and maintained (Besom 2013: 11-14, 211-212, 271; Cobo 1979: 266; Kolata 2012: 104-105; Bruhns 1994: 391-392; Silverblatt 1987: 229). While all other aspects of Inka hegemonic imperial administration are crucial to its function, the mit'a is of utmost interest in this thesis as it allowed for the creation of the monument the Inka's monumental road system that spans the Andes.

Economic Order

The economy of the Inka was not a traditional market economy, but rather a pastoral one with heavy reliance on pooled resources. Pre-Inka economies were variable. Highland communities were often self-sufficient and lacked markets, systems of taxation, or temple economies that the Inka could easily use to divert goods to Cuzco. On the other hand, coastal communities often had specialized and interdependent economies that the Inka could not easily supervise. As a result of this range of simple to complex systems, the Inka chose to incorporate well-established highland economies and allow integrated systems to self-regulate. The Inkas used kin-based production and exchange rhetoric to represent their economy as an extension of familial obligation. Through this rhetoric, the Inka organized a rotating system of labor tax (mit'a) where peasants of the empire would tend state-owned agricultural fields and flocks; produce crafts in state-owned production centers; served in the military; and created infrastructure for Tawantisuyu. The products of the peasants' field and flocks were untouched by the Empire (Cobo 1979; D'Altroy 2015: 393-394; Falcón 1946; Garcilaso de la Vega 1966; Murra 1980, 1982; Polo de Ondegardo 1940). Cobo describes the mit'a the best (1979: 234):

> "One thing that should be pointed out with respect to the amount of tribute that they brought to the king, and it is that there was no other rate or limit, either of the people that the provinces gave for the mit'a labor

> service or in the other requirements, except the will of the Inka. The people were never asked to make a fixed contribution of anything, but all of the people needed were called for the aforementioned jobs, sometimes in larger numbers, other times in lesser numbers, according to the Inka's desire, and the result of those labors was the royal tribute and income; and in this way the people extracted all the gold and silver that the Inkas and the guacas [huacas] had."

Darrell La Lone (1982) describes this economic system as "supply on command", in contrast to capitalism's "supply and demand" model. Evidence of similar economic systems to the Inka has been observed among the Moche, Wari, Tihuanaco, and Chimu, all of whom intensified farming, herding, and artisanry within their conquered lands for statecraft purposes. For example, provisioning state activities or sustaining panaqas. Within the Tawantisuyu, goods produced for these purposes were kept in imperial waystations referred to as tampus (D'Altroy 2015: 395; Janusek 2008; Jennings 2010; Jennings and Bowser 2009; McEwan 2006; Moseley and Cordy-Collins 1990; Pillsbury 2001; Quilter and Castillo 2010; Schreiber 1992, 2001; Shimada 1994). Eventually, the Inka improved the tradition of intensifying labor by replacing rotating workers with permanent specialists and creating the specialized labor classes mentioned earlier.

Moral Order

Just as their economic order was dependent on land and labor, so too was the Inka's moral order. The Inka viewed the collective tasks of farming and herding and altering the landscape as acts of worship. In their system of beliefs, the physical landscape possessed human qualities and the power to affect human destiny. Consequently, the Inka codified their beliefs about roles, responsibilities, and their fate into the concrete practices of molding the landscape for their livelihood. Further, all aspects of nature were imbued with an animating force, known as camay, and could communicate with the inhabitants of the land through the mediation of shamans, healers, priests, and kings. Communication with the natural world was accomplished at locations on the landscape believed to be privileged points of access. These spaces are the huacas, many of which exist today, despite the attempts to destroy them by the Spanish. The huacas were integrated into a system of forty two lines radiating from Cuzco called the ceques (figure 2.3). Each ceque was assigned to a specific social group in Cuzco who performed rituals at the appropriate shrines according to a ceremonial calendar. Camay did not just penetrate the landscape, however, but also inhabited the bodies of the deceased. Thus, ancestor worship was another invaluable aspect of the Inka belief system. Illustrious leaders were assiduously and elaborately preserved and engaged with during rituals of remembrance and consultation (Bauer 1998; Cobo 1990: 51-84; D'Altroy 2015: 263-264; Kolata 2012: 146, 158).

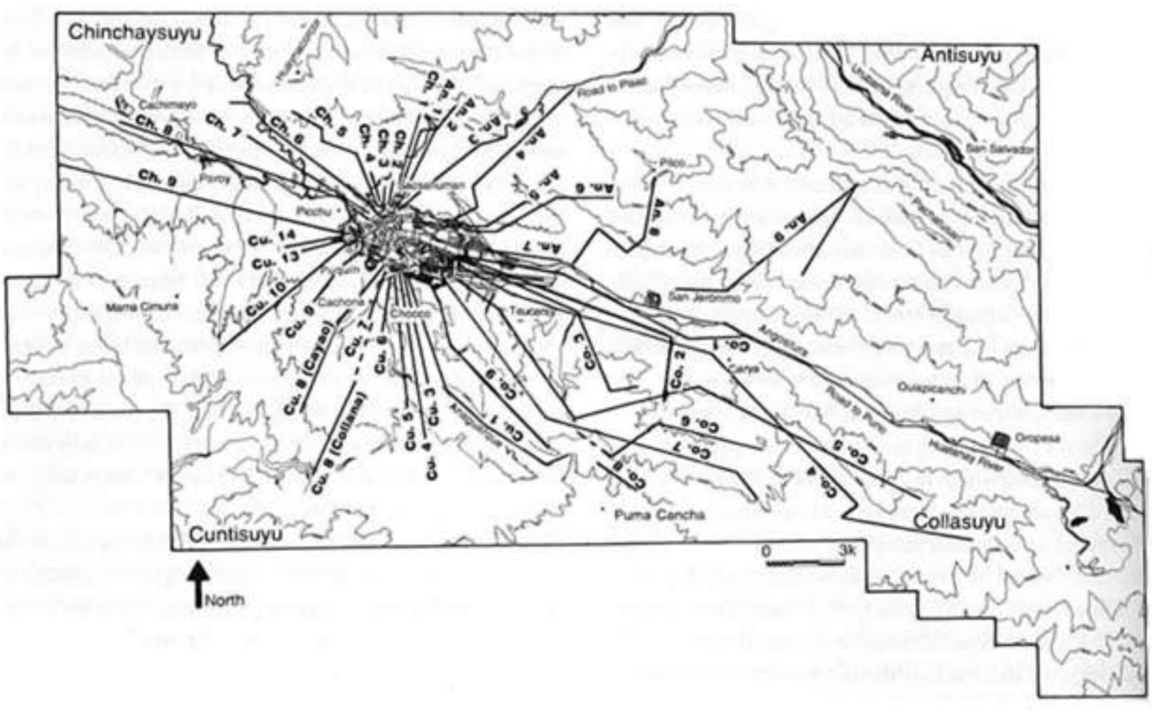


Figure 2.3: Cuzco Ceque System (Bauer 1998)

The deep connection the Inka had with their landscape means the study of their road system is a vital endeavor to understanding their culture. Hyslop acknowledges the importance of understanding this spiritual connection in his work on the Inka road system, however, his inclusion of the cultural aspects of the Inka roads was cursory (1984). Since Hyslop, there has been a paucity of work on the Inka roads until Jenkins and Julien (2001; 2012). Jenkins does not examine the significance of the roads in great detail, but Julien is more thorough. Her chapter on the Chinchaysuyu road in the *Highways, Byways, and Road Systems in the Pre-Modern World* anthology discusses the intertwining of the panaqas, ayllus, mitmaq, and the road system in significant detail (Julien 2012: 153-157).

3. ARCHAEOLOGY OF ROADS

Now that a basis for understanding the Inka road system in relation to the history and culture of the Inka Empire has been established, I will place it in context of the archaeology of road systems. Anthropology has recently experienced a resurgence in the research on the cultural implications of road systems and provides a decent theoretical grounding. Archaeology of roads provides more background for this thesis with its well-developed criteria for the archaeology of state-level road systems. Both of these schools of thought are then synthesized in relationship to the Cuzco to Vilcashuaman portion of the Chinchaysuyu road.

ANTHROPOLOGICAL THEORY OF ROADS

The construction of roads to ease travel is ubiquitous phenomenon in both the ancient and modern world. However, roads are more than a utilitarian aid in the movement of human beings. Roads articulate political and material history of the region and render these spaces controversial. The planning and construction of roads necessitates the accommodation of competing interests and expectations of all involved parties and the handling of the moral complexities of establishing infrastructure for the public good. The anthropological study of roads encompasses the questions of materiality, human subjects, states, societies, politics of infrastructure development, and cultural conditions of everyday life (Dalakoglou and Harvey 2012: 459-461). Roads can be utilized to demonstrate absolute dominance over conquered territories and maintain their subjugation or to facilitate social integration; as means of communication and to spread ideologies; as a mode of expressing individual wealth or the affluence of a civilization; as a form of public infrastructure or a restricted elite space (Alcock *et al.* 2012: 3-5; Kantner 1997: 49-52). Due to their large geographic and chronological scope and their effect on the quotidian lives of all manners of people, roads and their construction have been imbued with far greater social, ideological, and political significance than their utilitarian purpose belies.

Prior to the 1980's, anthropologists researched roads as a means of establishing spatial-cultural boundaries that defined and contained cultural groups. The identifying of cultures by a set of cultural traits tied to identifiable locations was termed space-culture isomorphic by Gupta and Ferguson (1992; 1997). Recently, space-culture isomorphism is less favored. Instead, roads are proposed to be interfaces that create and consolidate boundaries but also revise the boundaries through their inherent purpose of connectivity. Roads are simultaneously a tool of boundary formation and deformation (Dalakoglou and Harvey 2012: 461-462).

ARCHAEOLOGY OF ROADS AT THE STATE LEVEL

Interest in archaeologically investigating roads began with the rise in popularity of air survey for remote sensing in the beginning of the 1920's. With the ability to view the landscape from above, random geographic features could be identified as settlements and roads and easily mapped (Collier 2002). O.G.S Crawford was one of the first to utilize this newfound ability of aerial survey in Southern England and argued for more widespread use of the technique (1923). Archaeology of roads was still slow to develop. To this day, comparative anthologies of archaeological texts on roads are rare. Two have been published recently: *Highways, Byways and Road Systems* in 2012 and *Landscapes of Movement: Trails, Path, and Roads in Anthropological Perspective* in 2009. As a result, a timeline of the archaeology of roads is hard to establish, but archaeological publications researching roads start appearing in the 1950's with the roads of the Roman Empire (Margary 1955). Work on roads outside of Europe followed twenty years later in the 1970's with work on the sacbe'ob of the Maya (Sabloff and Rathje 1975). Archaeological research on roads is only gaining more traction and new insights are being gained on the roads of ancient civilizations.

Performing archaeological research on the chronology of roads is complicated by their frequent reuse and the involvement of multiple site to regional scale archaeological components. These archaeological components include the roads themselves, resting places, crossing points, and settlements. In order to fully study a road system, an archaeologist must integrate historic information, geographic and archaeological data, and incorporate it into the operational principles of state-level road building and use. Researching roads is typically linked with the study of imperialism as a means to investigate socio-cultural issues, such as power, politico-economic organization, and concepts of boundaries. The use of roads to research imperial states is underpinned by the stages of empire: expansion, consolidation, and collapse (Hendrickson 2010: 480-481).

Four operational principles on the research of state-level transportation and state development have evolved. The first principal is that groups often reuse routes instead of constructing new ones. Secondly, within a road system not all roads experience continual or universal use. States will shift preference from individual roads or even to different modes of transportations (Hendrickson 2010: 481; Needham 1970: 30). The next principle is that road systems require significant effort and resources for construction and maintenance. As a result, the creation and formalization of roads is linked to periods of economic or political expansion and consolidation when sufficient manpower is available. Finally, transport technology and infrastructure are rarely homogenous in type and distribution across a system and are dependent on terrain and distance from core territories (Hendrickson 2010: 481). The development of state-level transportations is well researched in the British and mainland European Roman roads, in

Imperial China, protohistoric to Mughal India, and the Inka Empire. Research into these regions has produced seminal works leading to the development of the operating principles listed earlier.

Influential Studies in the Archaeology of Roads

The Roman roads were some of the first roads investigated under the auspices of state-level development. Construction on these roads began around 500 BC and grew as the Roman Empire expanded and consolidated itself. The roads were an efficient means to move armies, officials and civilians, and the transportation of official communications and trade goods overland. These roads ranged from small, local streets to broad, long-distance highways. Highways in the Roman Empire followed accurately surveyed courses and connected cities, towns, military bases, and administration centers. Major roads in Rome were typically paved with stones and well-drained. Along the roads were footpaths, bridleways, and drainage ditches. At the height of the Roman Empire, at least twenty nine military highways radiated from the capital and the one hundred and thirteen provinces were connected by three hundred and seventy two road links. The entire system totaled over 400,000 kilometers of roads and over 80,500 kilometers of the system were stone-paved (Davies 1998).

From the research done on the roads of the Roman period in Britain and mainland Europe, the first principle of state-level transportation and state development was formulated. Forbes (1964), Margary (1955), and Chevallier (1976) each proposed that the Romans often integrated previously-existing roads instead of constructing new ones (Hendrickson 2010: 481). However, due to the time period that the listed archaeologists were working in, all handled the use of roads in a purely functional manner. Scholars, notably Witcher, criticized this functionalist viewpoint (1998). Regardless, the work of Forbes, Margary, and Chevallier was revelatory in their acknowledgement of the incorporation of previous roads by an empire.

The second principle, that not all roads experience continual or universal use within a road system, was first introduced in Needham's research on the roads of Imperial China in 1971. During the Chhin state and dynasty, a flurry of road building activity began, starting around 220 BC. The roads constructed were wide and surfaced with stone. Steep slopes were climbed by stone stairways. By 700 AD the Imperial Chinese road network was about 40,000 kilometers. Needham argues that as Imperial China developed though, demand for terrestrial transportation decreased. By the late imperial period, rivers became preferred modes of transport, and roads bordering waterways were altered to facilitate the towing of barges with pack animals. Roads without access to rivers experienced less use and some were abandoned (Needham 1971). Needham proposed the shift in preference between individual roads or even to different modes of transportations was a common characteristic of large road systems and his hypothesis has been widely adopted (Hendrickson 2010: 481).

The roads in India are equally expansive to those mentioned previously and are even older. The Indus civilization in Sindh, Balochistan, and the Punjab existed from 3250-2750 BC and paved their major streets, which were also well-drained, with burned brick cemented with bitumen. The tradition of road building continued in India and by AD 75 several methods of road construction were common. These methods include brick or stone slab pavement laid on top of a concrete foundation and then grouted with gypsum, lime, or bituminous mortar. By the beginning of the Common Era, street paving was a ubiquitous practice. From 300 to 150 BC, both northern and western India had developed a network of roads. The Mauryan Empire in the fourth century BC even had a road stretching from the Himalayan border, through Taxila and Punjab, all the way to the mouth of the Ganges River. Road building as a means of empire formation only continued through the Mughal Empire (Deloche 1993).

Deloche covered the history of road building on the Indian sub-continent in his work *Transport and communications in India prior to steam locomotion: Volume I: land transport*. He concluded that although construction on roads was common, it typically coincided with periods of economic or political expansion and consolidation when sufficient manpower is available. This is due to the fact that road systems require significant effort and resources for construction and maintenance. As a result, their maintenance can only be performed in conjunction with imperial expansion and consolidation. Since publishing his research in 1993, his conclusion has become essential to the research of state development and road systems (Deloche; Hendrickson 20120: 481).

Hyslop's 1984 *The Inka Road System* remains the formative work on studying the relationship between state development and road systems for South America. His main contribution to this research question is his acknowledgement of the heterogeneity of the roads in the Andes. After completing comprehensive survey of portions of the Inka road system from Ecuador to the Atacama Desert, he concluded that the means of constructing a road in the Inka Empire was not mandated by imperial style but by the availability of local resources and the terrain that was encountered (Hyslop 1984). While some states may have created homogenous roads throughout their lands, Hyslop's work illustrates that homogeneity is not a prerequisite for state-level road systems. In fact, Hyslop was the first archaeologist to come to this conclusion and is cited as the source for this operational principle for the research of transportation and state development (Hendrickson 2010: 481). However, he also incorporated the first principle into his work: groups often reuse routes instead of constructing new ones. During his survey, he made note of several segments which he believed to have been constructed by previous Andean cultures. He identifies roads of possible pre-Inka origins at Cajamarca, Peru, Huaytara-Pisco River Valley, and Cuenca, Ecuador (Hyslop 1984: 273).

Hyslop's Research on the Inka Road System. The scale of Hyslop's research is immense, and as a result he was able to effectively analyze their importance and scope. In his analysis, he determined that the factors determining the location of the roads were geographic and cultural. The Andes is a region of widely variable terrain, which of course factored into the construction of roads; however, the cultural factors of Inkan road building were more complex. The first cultural objective of the roads were to connect disparate populations. By connecting populations in the Andes, the Inka were able to use the road system as a network for acquisition, management, movement, and protection of labor. As a result, roads often lead to the borders of the Inka Empire, where populations were either recently acquired or needed protecting from outsiders, and to heavily-populated areas. When the roads passed through regions of low population density, it was only to connect high-priority regions. Roads were also built with religious, military, administrative, and economic goals. The roads leading to the Copacabana Peninsula and the Island of the sun or the road to the Guanacaure shrine in Huánaco, Peru are a few examples of roads built almost exclusively for religious purposes (Hyslop 1984: 248; Bandelier 1910; Beorchia Nigris 1978; Ortiz de Zúñiga 1967). Military roads were typified as the branch routes that led to the borders of the Empire and usually terminated in fortresses. Examples of these are seen on the eastern slopes of the Bolivian Andes and in the Chupaycho region of Peru (Hylsop 1984: 248; Nordenskiold 1924; Polo De Ondegardo 1917: 98). Most of the roads in the Inka road system were administrative and economic to some degree as they connected administrative centers and allowed for the movement of resources. A primarily administrative route crosses the Atacama Desert. It is believed to be almost solely administrative as its purpose was to connect Central Chile with Cuzco. Pre-Inka cultural heritage also played a role in determining the route of an Inka road. Pre-Inka roads were often adopted into the road system if they were built along the only possible route or if they already connected settlements the Inka wanted to acquire into their empire. This is seen at the modern cities of Cuenca, Ecuador, Farfán, Cajamarca, Chincha, Pachacamac, Paria, and Puerta de La Paya (Hyslop 1984: 245-49).

Hyslop also investigated the relationship of the tampu system with the road system. Tampu were lodgings and storage areas located along the Inka roads. The tampu were located a day's walk apart, served by the mit'a labor of the nearby settlements, and provided lodging and supplies to travelers on state business. The tradition of tampu was pre-Inka and continued into Spanish colonial times long after the fall of the Inka Empire. They were invaluable to the function of the road system as an administrative infrastructure and provided state-sanctioned travelers with resting places. They were another means of extracting tributary labor and goods from local populations, as well (Hyslop 1984: 275-276; Murra 1980: 105-106,125-126; Regal 1936: 12-14; Rowe 1946: 231; Erdmann 1963: 62-69).

Of great interest to this thesis in particular is Hyslop's analysis of the importance of the Chinchaysuyu. This road had the largest concentration of Inka population centers in the empire and it is the widest and most formally constructed road in the entire system. At the road's narrowest it is three meters and sixteen meters at its widest. The Chinchaysuyu road is also described the most frequently in early historical accounts due to its impressive construction. Hyslop noted that the road bifurcated multiple times. One of these bifurcations is at Huánaco. While Hyslop argues that this road was the most important road of the empire, it was still rivaled by roads leading to the Pacific Coast and to Qollasuyu (Hyslop 1984: 258-259).

THE CHINCHAYSUYU ROAD FROM CUZCO TO VILCASHUAMAN

Despite the insights provided by Hyslop's work, the qualitative descriptions provided by historical travelers are still relied upon heavily when researching the Inka road system, especially main highways, and the importance of individual cities. Vilcashuaman was a large, planned installation for Inka hegemonic administration of the surrounding province and was originally known as Wilka Waman which translates to sacred hawk (D'Altroy and Schreiber 2004: 268; Julien 1983). The city was founded on the edge of the Chanka territory conquered by the first Inka ruler Pachakuti (Bull 1946: 206-208; Cobo 1979, 1990; Sarmiento 1906; Schreiber 1992: 51). Soon after the conquest the Inka removed the local population and replaced them with 10,000 mitmaq from other parts of the Empire along with administrative kin (Garcialosa 1966; Murra 1980: 179; Schrieber 1992: 57-58). The colonists included Anta people and replaced the original inhabitants, the Tanquihua (Bull 1946: 188). The total removal of the population may be because the region had complex political organization and/or it represented a direct threat to Inka control. As a result, the Inka deemed it more favorable to eradicate previous political organization and institute their own, leading to the creation of Vilcashuaman.

The establishment of Vilcashuaman was undoubtedly for strategic reasons. According to Cieza de Leon (2010: 312), the distance from Cuzco to Vilcashuaman was a little over sixty leagues and that a traveler must head south from Ayacucho to Vilcashuaman before continuing on to Cuzco:

> "The distance of the city of Guamanga [Ayacucho] to that of Cuzco is sixty leagues, a little more or less. On this road is the plain of the Chupas, where the cruel battle was fought between the governor Vaca de Castro and Don Diego de Almagro the Younger. Further on, still following the royal road, are the edifices of [Vilcashuaman], eleven leagues from [Ayacucho]."

According to Inka myth, there were underworld passages between imperial centers, such as Cuzco and Vilcashuaman, which could be traveled in the span of one day by one of the aya poma, aya uaman, and aya condor: mountain lion, hawk, and condor spirits. Aya poma, aya uaman, and aya condor were held in great respect by the Inka Empire; according to Guaman Poma de Ayala, “A good man could walk for seven days. In one day he would go from Cuzco to sleep at Vilcas, and from there on to Tayacaja, to Anchicocha, arriving at Los Reyes de Lima for lunch” (figure 3.1; Guaman Poma de Ayala 1944: 268).

Figure 3.1: Distances between major Inkan cities (Gutierrez 2015: personal communication)

Vilcashuaman was considered by the Inka to be “the centre of the dominions of the Yncas; […] that from Quito to Vilcas is the same distance as from Vilcas to Chile, these being the extreme points of the empire. Some Spaniards, who have travelled from one end to the other, say the same” (Cieza de Leon 2010: 312; Schrieber 1992: 57-58). The site is located on the main highland road (the Chinchaysuyu road) and it is at the intersection of at least one, maybe two, roads leading to the coast. The centrality of Vilcashuaman is further supported by Jenkins' network analysis of the Inka road system. Through his analysis, he found that Vilcashuaman had the greatest potential to control the flow of information or goods from one administrative center to any other center (figure 3.2; Jenkins 2001).

Figure 3.2: Governor of the royal roads (qhapaq ñan tocriroc) of Vilcashuaman (Guaman Poma de Ayala 1614)

Vilcashuaman is also demarcated as a place of great importance by a high concentration of elite and administrative architecture. These included a temple of the sun, palaces, and storehouses (Cieza de Leon 2010: 312-313):

> "Ynka Yupanki ordered these edifices to be built, and his successors added to them. The temple of the sun was large and richly ornamented. On one part of the plain, towards the point where the sun rises, there was a chapel for the lords […] By the side of the chapel were the palaces of Tupac Ynca and Yupanqui, and the other great buildings, besides many storehouses where they put the arms and fine cloths, with all other

> things paid as tribute by the Indians of provinces within the jurisdiction of Vilcas, which was, I have heard it in other places, the head of the kingdom. Near a small hill there were, and still are, more than seven hundred houses, where they stored up the maize and other provisions for the soldiers who marched that way."

The temple of the sun, according to Soto and Cieza, housed a group of ayllakuna known as the Virgins of the Sun to the conquistadors and priests. The temple was guarded by forty men and serviced by men from the surrounding villages (Barrenechea 1962: 572; Cieza de Leon 2010: 313; Murra 1980: 123, 127).

> "The temple of the sun […] had two doorways, approached by two flights of stairs, having […] thirty steps apiece. Within this temple there were the lodgings for the priests and the virgins […] These buildings were served by more than forty thousand Indians, divided into relays, and each chief understood the orders of the governor, who received his power from the Ynca. To guard the doorway alone there were forty porters."

In addition, Vilcashuaman houses a finely constructed usnu platform. An usnu was most likely a shrine with a sacred object, such as a pointed stone, placed on top of a flat platform. These platforms could be several levels high. The usnu platform at Vilcashuaman has four levels (Schrieber 1992: 58).

Upon leaving Vilcashuaman, Cieza de Leon made note of different landmarks along the Chinchaysuyu road and described the route in more detail. In addition, we learn more about the construction of Inka bridges (Cieza de Leon 2010: 314-315):

> "From Vilcas the road passes to Uramarca, which is seven leagues nearer Cuzco, and here the great river Vilcas is crossed because it is near these buildings. On each side of the river there are very large stone pillars made very strong and with deep foundations. From these pillars a bridge of ropes, like those used for drawing water with a wheel, is slung across the river. These ropes are so strong that horses may pass over with loosened rein, as if they were crossing the bridge of Alcantara, or that of Cordova. The bridge was one hundred and sixty-six paces long when I passed over it. The river rises in the province of the Soras […] and the […] Lucanas […] The Ynka esteemed the Soras and the Lucanas so highly that their provinces were

favored, and the sons of their chiefs resided at the court of Cuzco. There are storehouses in these provinces […] Returning to the royal road, the traveler reaches the buildings of Uramarca, which is a village of *Mitimaes*, for most of the natives were killed in the wars of the Yncas."

The bridges of the Inka Empire, like the one Cieza de Leon described, were constructed and maintained under the same mit'a labor tax utilized for the roads and were woven out of local plant materials. To build a bridge, plant fiber cables were pulled taut and secured onto the banks; the larger bridges were reinforced with a network of branches woven to form a walkway and secured to stone platforms on both banks. Inkan bridges hung low over rivers and thus were highly susceptible to wind. The middle of the bridge swayed in all weather conditions. Many Spanish explorers crawled across the bridges during their first crossing. Some of the larger bridges often could not be used in the afternoon as a result of cross winds (figure 3.3; Bauer 2006: 470-475; Garcilaso de la Vega 1966; Diez de Betanzos 1996).

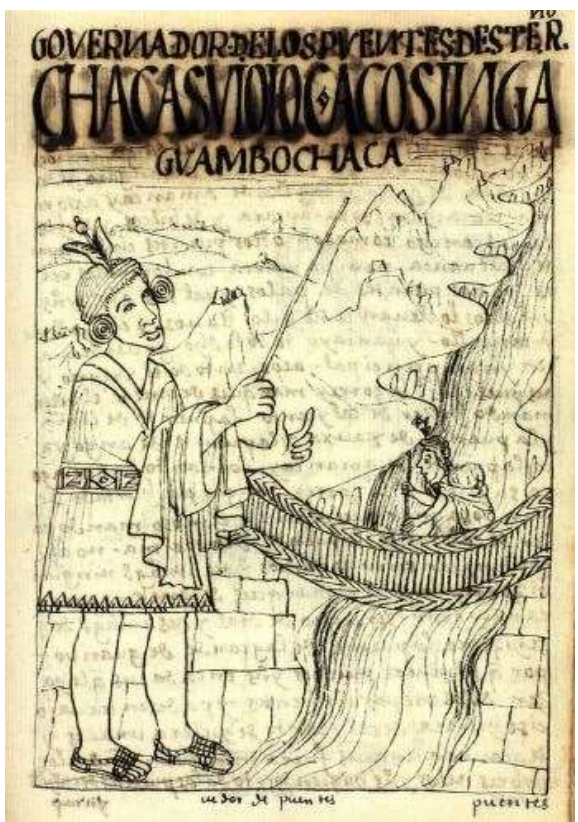


Figure 3.3: Governor of the bridges (chaka suyuyuq) of the Inka Empire (Guaman Poma de Ayala 1614)

The Rio Pampas, known to Cieza de Leon as Rio Vilcas, was crossed at two locations. Cieza de Leon crossed at Uranmarca but the other is between Orcos and Chincheros. As with all bridges in the Inka Empire, these bridges not only tackled the difficulty of crossing rivers and valleys but also connected important centers of regional power. The bridge near Uranmarca that leads to the east emerges above Queca and allowed the Inka to connect Vilcashuaman to large administrative centers of the Empire like Soras, Abancay, Andahualyas, and Cuzco (Bauer 2006: 484; Schreiber 1992: 160). The bridges were also used as means to control revenue. In the case of the bridge between Orcos and Chincheros leading north, whichever community controlled the bridge could collect tolls from travelers (figure 3.4). This bridge was in use well past 1906, when new stone and mortar towers were built, and was approved to be replaced with a metal suspension bridge in 1849 (Bauer 2006: 484-486; Hyland 2011). However, this bridge and the trail leading up to it were most likely pre-Inka and of Wari origin but used through the Inka Empire and onward. The trail leading to this bridge is now badly eroded but it eventually meets a larger road that heads north from the valley. This trail is unlike the Inka road because it has large steps made out of andesitic basalt in the steeper sections instead of being paved with basalt. This road passes adjacent to the Wari site of Willkaya, and then heads north past Vilcashuaman to the Ayacucho Basin; the center of the Wari Empire (Schreiber 1992: 160).

After crossing the Rio Pampas at Uranmarca, Cieza de Leon traveled to the Andahualyas province and encountered people of Chanka origin. In the Andahualyas province, the road crosses the Rio Abancay, nine leagues from Cuzco. The bridge crossing this river demonstrates the typical Inka construction of a rope bridge attached to stone pillars (Cieza de Leon 2010: 318). He continued on to the river of Apurimac (Cieza de Leon 2010: 320):

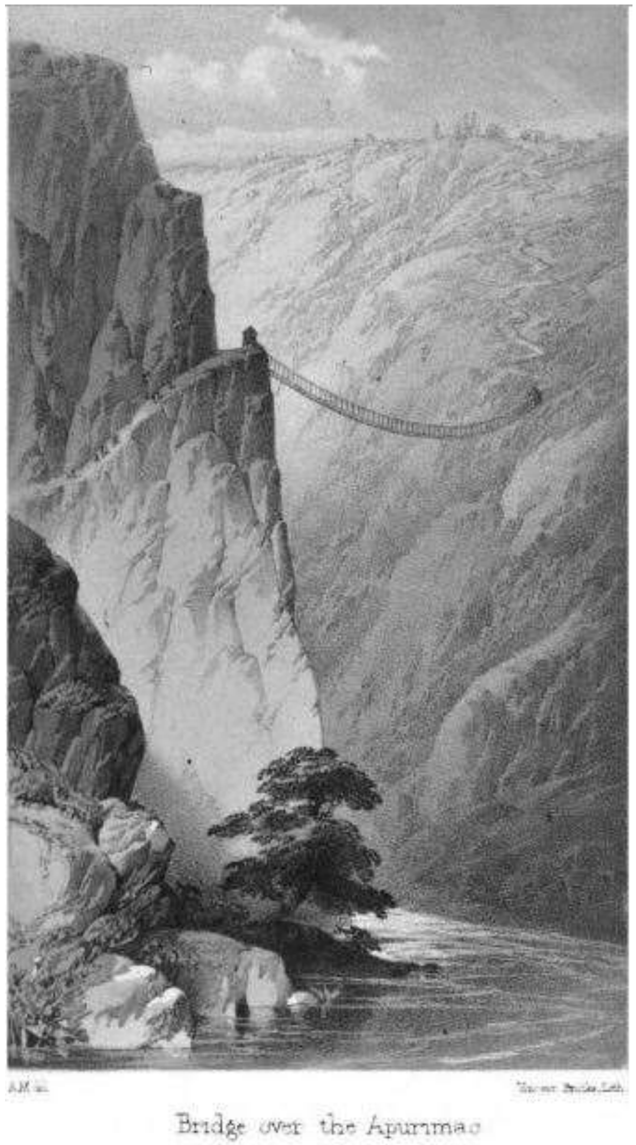


Figure 3.4: Drawing of the Apurimac Bridge (Bauer 2006)

"It is eight leagues from that of Abancay, and the road is much broken up by mountains and declivities, so that those who made it must have had much labour in breaking up the rocks, and levelling the ground, especially where it descends towards the river. Here the road is so rugged and dangerous, that some horses, laden with gold, have fallen in without any possibility of saving them, there are two enormous stone pillars, to which the bridge is secured. When I returned to the City of the Kings, after we had defeated Gonzalo Pizarro, some of our soldiers crossed the river without a bridge, which had been destroyed, each man in a sack fastened to a rope passing from the pillar on one side of the river to that on the other."

The bridge across the Rio Apurimac was the largest bridge in the Inka Empire near the modern town of Curahuasi. The bridge was connected to the banks with stone platforms and four stone towers. The bridge was replaced annually; a task that took two weeks and two hundred and fifty people to complete. Even though it was built at the narrowest portion of the Apurimac River Valley, the bridge was still around 148 feet long and hung 118 feet over the river (figure 3.5). It was built into some of the steepest banks in the valley (Bauer 2006: 477-478; Garcilaso de la Vega 1966; Regal 1972). The Inka even constructed a tunnel in order to reach the narrowest portion of the gorge. Lardner Gibbon described the tunnel during his visit to Peru in 1851 (Gibbon 1854: 37; Bauer 2006: 478).

> "Our view [of the river] was cut off by another turn, and leaving the surface of the earth, we enter a tunnel, cut into the mountain, which stands like its strata, perpendicular, by the side of the river. Sky-light holes are cut through the rock, and as we travel along, in alternate light and darkness, the arrieros shout at the top of their voices at the train. The mules are fearful of proceeding. Coming to a house, which was open on both sides, we looked over the Apurimac bridge, and then down into the river, a fearful distance below. . . . The ropes of this suspension bridge—of bark, about the size of a sloop-of-war's hemp cables are made fast to the posts which support the roof of the house."

Cieza de Léon reported that the bridge had been destroyed sometime around two decades after the conquest. It was later rebuilt and eventually abandoned in 1880 (Bauer 2006: 481).

Cieza de Leon then journeyed to Limatambo, crossed the mountains of Vilcaconga, and entered the valley of Xaquixaguana. This valley is only five leagues from Cuzco and is filled with a river that forms a deep morass. The Inka were able to cross this morass as the road they built was broad with walls on either side (Cieza de Leon 2010: 320). Finally, Cieza de Leon reached Cuzco which he described as rugged and surrounded by mountains. The city is located on the banks of two east-flowing streams and at the start of a valley. At the time of his journey, the valley of Cuzco was sparse with few fruit-yielding trees and it is cold. On the tallest and

Figure 3.5: Photograph of Pampas River Bridge (Bauer 2006)

nearest mountain stood the ruins of a fortress with only the foundations remaining (Cieza de Leon 2010: 322).

Other useful accounts are provided by the Spanish conquistadores. On November 15, 1532, Pizarro and 168 other Spaniards arrived in the Inka city of Cajamarca after landing in the city of Piura. There they encountered the emperor Atahualpa. They took him captive, collected a large ransom, gathered reinforcements, and then sentenced him to death on the July 26, 1533. Prior to Atahualpa's execution, Pizarro crowned Atahualpa's brother, Túpac Huallpa, ruler. The execution of Atahualpa instigated rebellion amongst the Inka led by Atahualpa's generals. As a result the conquistadores were forced to travel throughout the Empire to quell the revolt. The conquistadores were joined by Atahualpa's other brother, Manqu Inka Yupanqi (D'Altroy 2015: 1-2, 48).

One of the main strategies of the Inkan generals to hinder the progress of the conquistadores was to destroy the bridges. The general Quizquiz was responsible for this maneuver and most notably destroyed the bridge across the Rio Pampas prior to Pizarro's attempt to reach Cuzco in November of 1533. In order to reach Cuzco from northern Peru, Pizarro had to pass through Vilcashuaman. The bridge over the Rio Pampas is to the south of Vilcashuaman, and even before reaching the destroyed bridge, Pizarro and his troops spent most of November 6th trying to descend the narrow, 2,000 meter deep valley. During the descent, the horses lost most of their shoes. Upon reaching the river, the Spanish barely managed to swim across it. Similar hardships were faced in 1534 near the end of January, when a portion of Pizarro's forces led by Manqu Inca attempted to use the Chinchaysuyu road to fight in the Battle of Jauja. Their advance was slow due to heavy rains that had caused the rivers to overflow their banks and destroy some of the bridges. Manqu Inca and his soldiers were able to reach the still destroyed Rio Pampas bridge before they were forced to stop. The soldiers worked for twenty days trying to rebuild the bridge but were unable to due to the heavy current. Manqu Inca returned to Cuzco and his troop remained behind. In March they succeeded in crossing the river (Hemming 1970: 120-122, 162).

The same year Manqu Inka was trying to reach Jauja, de Soto decided to journey from Vilcashuaman to Cuzco in order to take the city while Pizarro was fighting. From his notes, we know that the Chinchaysuyu road crossed the Rio Vilcas (now known as the Rio Pampas), crossed by Abancay, Apurima, and then Limatambo, seven leagues from Cuzco. He was intercepted by two native messengers, from a group of over 300, who offered to ally themselves with his soldiers. The messengers claimed that all members of their group had suffered insult at the hands of Athuallpa and his generals. Soto and his troops believed this to be a trap and returned to Vilcashuaman. Upon Soto's return, he distributed the Virgins of the sun among his soldiers and would have destroyed the city if not for Pizarro's orders (Berrenechea 1962: 572).

Historical Analysis of the Chinchaysuyu Road from Cuzco to Vilcashuaman

The prevalence of the Chinchaysuyu road in the accounts of conquistadores supports the argument for its role as the main highland route for the Inka Empire. Further, all conquistadores arriving from the north were forced to pass through Vilcashuaman before arriving in Cuzco. This is in direct contrast to today where the modern road Pe-3s leads directly from Ayacucho to Cuzco and to get to Vilcashuaman from Cuzco, one must turn off Pe-3s onto a small carretera that was not constructed until the 1970's. This significant change in the accessibility of Vilcashuaman is due to the change in power centers after the Spanish Conquest of Peru. In 1535, Francisco Pizarro founded the city of Lima which became the capital in 1543, replacing Cuzco. Located on the coast, Lima was well suited to acting as the center for Spanish governance in Peru. From Lima, the Spanish were able to send ships back to Spain or to cities in southern Peru and receive goods from international trade. Cuzco still held influence, however, and was often traveled to by land from Lima. Vilcashuaman was no longer a site of high centrality, however, and the road from Lima to Cuzco was no longer diverted to reach it. Instead, large highways between Cuzco and Lima began to run through Ayacucho, which was more central to the needs of the Spanish and now the current government of Peru. Eventually, even Cuzco was no longer considered central until it experienced an influx of traffic with the 1918 construction of the railway from Lima to Buenos Aires (Hemming 1970; Higgins 2005).

Prior to the construction of the AY-104 and AY-105 to connect Vilcashuaman with the nearby Pe-3s, the fastest means of reaching Vilcashuaman was to walk about half a day from the nearest city of Ayacucho. Currently, Vilcashuaman is a small town occupied mostly by horsemen known as the Morochucos who claim to be direct descendants of the conquistadores. In and around the town are intact terraces, walls of Inka palaces, a temple of the sun, and a large usnu platform (Hemming 1970: 120-122). However, during the time of the Inka Empire, Vilcashuaman was drastically different. The city was centrally located, its founding resulted in the mass resettlement of local tribes, and there was a large amount of elite and administrative architecture.

Roads, whether ancient or modern, are built to connect places of social, political, economic, or military import to a culture. Following this logic, Vilcashuaman must have been immensely important to the Inka Empire since the northbound Chinchaysuyu road headed west to Vilcashuaman before turning north. This indicates that it was imperative to the Inka means that to funnel north-south traffic through this city and that the other cities along the road were also worth being connected to the administrative centers of Cuzco and Vilcashuaman. For comparison, today's situation, where Cuzco is now linked to Ayacucho indicates that Ayacucho is of greater importance to the country of Peru than Vilcashuaman.

Further, the Chinchaysuyu road from Cuzco to Vilcashuaman exemplifies many of the characteristics of the operating principles of the archaeological research on state-level transportation, primarily the third operating principle that the construction of road systems. The formalizing of the road from Cuzco to Vilcashuaman followed shortly after the defeat of the Chankas by Pachakuti. By conquering this region, the Inka were able to gather the resources and labor necessary for the construction of a mainland highway (Deloche 1993; Bull 1946: 206-208; Cobo 1890-95; Sarmiento 1907; Schreiber 1992: 51; Hendrickson 2010: 481). Further, due to the short span of time that the Inka Empire was in power, the settlements along the road most likely predate the Empire. Thus, there were probably already roads between the settlements that the Inka absorbed and formalized during their expansion. For example, the Wari bridge up-river from the crossing of the Rio Pampas (Hendrickson 2010: 481; Forbes 1964; Margary 1967;

Chevallier 1976; Adamska and Michecynski 1996; Bauer 1992; Bauer and Covey 2004; Covey 2006; D'Altroy 2015: 64, 85; Bauer 2006: 484-486; Hyland 2002; Schreiber 1992: 160). The other two principles that not all roads experience continual or universal use or that transport technology and infrastructure are rarely homogenous require a system-wide perspective of the Inka roads and cannot be argued for with only this portion of the road (Hendrickson 2010: 481; Needham 1970: 30; Hyslop 1984).

4. SPATIAL ANALYSIS IN ARCHAEOLOGY

The archaeology of roads has been greatly encouraged by the introduction of spatial analysis and remote sensing to the field in the 1970's. Remote sensing and spatial analysis is attractive to archaeologists because it allows for the modeling of hypothetical networks of travel and interaction of ancient cultures. By researching the means of movement for a culture, archaeologists can elucidate economic, political, and social relationships facilitated by travel. Recently, these means, particularly least cost path analysis is being used in Andean archaeology to good effect.

REMOTE SENSING AND GIS

Development of Remote Sensing

The history of remote sensing began in 1858 when the first aerial photographs were produced by Gaspard Félix Tournachon from a hot air balloon eighty meters over Bievre, France. Tournachon's methodology was soon accepted, and by 1860, James Wallace Black used aerial photography from hot air balloon to aid the planning of Boston. Aerial reconnaissance via hot air balloons was supposedly used during the American Civil War, but this claim is not well-substantiated (Collier 2002: 159; Chuvieco and Huete 2010: 5). During the 1880's, the British introduced the use of kites to obtain aerial photography. Kites were used to hoist a panoramic camera that captures the 1906 San Francisco earthquake. Around the same time as the 1906 earth quake, smaller cameras were attached to carrier pigeons (Chuvieco and Huete 2010: 5). Wilbur Wright introduced the use of planes to remote sensing in 1909 when he shot aerial photographs from his plane over Italy; by 1915, the British Royal Air Force had adopted airplanes for aerial reconnaissance (Collier 2002: 159-161; Chuvieco and Huete 2010: 5).

Starting in the 1920's, archaeologists realized that the same air survey that allowed for geographers to create topographic maps with greater detail, ease, and accuracy could be applied to their field (Collier 2002; Crawford 1923; Parcak 2009). In 1923, O.G.S Crawford, the "Father of Aerial Archaeology", introduced his argument for the applicability of air survey to archaeology at a meeting of The Royal Geographical Society (Hauser 2009). An archaeologist of pre-Roman and Roman United Kingdom, he believed the use of aerial photography would greatly improve the study of settlement and construction patterns in the archaeological record. According to him (Crawford 1923: 392):

> "It is the great merit of air-photographs that they reveal earthworks upon ploughed land which are invisible to the observer on the ground, or which appear to him only as a confused tangle. This was forcibly brought home to me when I walked over the fields near Windmill Hill, Hampshire. From the air an orderly system is visible. The bands of lighter-coloured soil are the field boundaries of a vanished agricultural community […] It was possible to detect this fact on the ground, but quite impossible to see there any system at all, and it would have been almost impossible to construct an accurate plan. With the help of air-photographs, however, this can be done."

Crawford's argument was well-received by The Royal Geographic Society and aerial photography quickly became a commonplace practice (Crawford 1923; Parcak 2009). Most notably, Charles Lindbergh was hired to take aerial photographs of Chaco Canyon and various Mayan cities in the Yucatan Peninsula in 1929 (figure 4.1; Parcak 2009: 17).

In 1930, Russia developed the first aerial multi-spectral photographs. The first non-visible film was developed soon after in 1931 by Kodak Research Laboratories. World War II led to the advancement of the development of color infrared film, thermal scanners, and imaging radar systems (Chuvieco and Huete 2010: 5-6). During World War II, archaeologists took advantage of the military reconnaissance aerial photographs created by German, British, and American forces to document and try to protect archaeological sites. In 1954, infrared


Figure 4.1: Photograph taken of Chaco Canyon by Charles Lindbergh in 1929 (National Endowment for the Humanities)

photography was introduced to archaeology by J. Buettner-Januch and his work on Barbeau Creek Rock Shelter in North Carolina. Buettner-Januch argued that IR photography represented archaeological remains more distinctly than regular film; however, IR film was more difficult to develop. The popularity in the application of aerial photography to archaeology began to decrease from 1958-1960. This was most likely due to the reallocation of government funds to space and satellite technologies in response to the Cold War. However, this diversion of government funding allowed for the possibility of remote sensing by satellite (Parcak 2009: 13-20, Lasaponara and Masini 2012: 9-14).

Satellite Remote Sensing

The first images taken from space were created in New Mexico during the 1940's to 1950's. Cameras were attached to V2 rockets and launched at the White Sands Proving Ground. The V2, the Viking, and the Aerobee projects did not produce high-quality photographs, but they did introduce the possibility of imagery taken from space (Chuvieco and Huete 2010: 6; Lasaponara and Masini 2012: 9; Parcak 2009: 20). The start of the Cold War fueled the development of remote sensing and rockets were replaced by satellites as the preferred means of gathering data. Between the 1960's and 1970's extensive archives of classified aerial photographs were created (Chuvieco and Huete 2010: 6-7; Lasaponara and Masini 2012: 9-14). The first satellite for non–military purposes was the Earth Resources Technology Satellite (ERTS); it was launched in 1972. ERTS was renamed Landsat in 1975 and was the first source of high-resolution, multi-spectral images for the entire Earth's surface. This program was accompanied by other projects like the manned Skylab, the oceanographic satellite Seasat, and the Heat Capacity Mapping Mission (Chuvieco and Huete 2010: 7-8). The Landsat Thematic Mapper (TM) was introduced to the satellite program in the 1980's. At a resolution of 30 meters, it was one of the highest spatial resolution sensor available at the time for civilian use. Clark *et al.* and Sever used this data for their research on ancient agricultural systems and field divisions. It was also used in paleo-environmental studies through photointerpretation by Parry, Drake, and White and El Asmar. The French Systeme Pour l'Observation de la Terre (SPOT) was launched in 1986 and produced data of a higher resolution (10 m) than TM; however, it was rarely used in archaeology due to its expensiveness (Chuvieco and Huete 2010: 8; Lasaponara and Masini 2012: 9-14).

In the 1990's intelligence satellite photographs taken by Russia and America were made commercially available for non-military purposes. Archaeologists rushed to apply the released images to their work, especially since the data from Russian Satellites was only available for four years. The data from the Russian Satellite KVR-1000 was utilized by both Fowler and Comfort on different sites in Europe. Fowler used the data to identify crop and soil marks near Stonehenge while Comfort investigated the Greek and Roman city of Zeugma in Turkey. Marcolongo and Morandi Bonacossi used similar data from Soyuz Kate-200 to research ancient irrigation and cultivation in Yemen (Lasaponara and Masini 2012: 1-7).

Once the Russian declassified data expired, American data from the KH-4B Corona missions were more widely used. Fowler and Kennedy were among the first to apply the Corona data to their research. Fowler used this data to research a hill fort in Hampshire and Kennedy applied it to his work in the Euphrates Valley. In 2003, Ur was able to discover road system dating to the Early Bronze Age in North-eastern Syria in the Upper Khapur basin. Unfortunately, geometric rectification of the Corona data are problematic because the Corona data were collected by a non-metric camera on a satellite with a decaying orbit. Goosens *et al.* attempted to decrease this distortion in their work on the Altai Mountains. Other researchers hope to improve the Corona data by integrating it with ASTER or IKONOS multispectral satellite imagery. Starting with the 1999 launch of IKONOS, very high resolution satellite data are available from private companies, and this has only encouraged the availability of satellite data produced by private companies and governments from all over the world. Now, a comprehensive distribution of data are available from IKONOS, QuickBird, OrbView, ASTER, SPOT, Indian Satellites, and EROS. This is in contrast to the aerial imagery collected during World War I, World War II, and the Cold War. The data collected then were focused on militarily advantageous zones such as

North America, Europe, and the Middle East (Chuvieco and Huete 2010: 8; Lasaponara and Masini 2012: 1-7).

The two most prevalent sources of satellite remote sensing data are the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and the Shuttle Radar Topography Mission (SRTM). ASTER is one of the imaging instruments onboard the satellite Terra. Terra was the first satellite launched through the NASA's Earth Observing System (EOS). A cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI), and Japan Space Systems (J-spacesystems), ASTER was launched in December 1999; its data are used to create land surface temperature, reflectance, and elevation maps (NASA 2004). The SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). On February 11, 2000, it was sent into space onboard the Space Shuttle Endeavour. Its sole purpose was to gather topographic data using two radar antennas. The SRTM has created a near-global high-resolution database of the Earth's topography (NASA 2005). Though developed around the same time, debate remains about the relative merits of these data sources. Racoviteanu *et al*. argued with their work at Nevado Cropuna that SRTM is the more reliable elevation data set and does not demonstrate the significant vertical bias of an ASTER DEM (2007). The specified SRTM accuracy standard is between ±16 m by Rabus *et al*. (2003) and ±19.35 m according to Tighe and Chamberlain (2009; Rademaker *et al*. 2012: 36). Meanwhile ASTER accuracy standard has been reported to be between ±18.64 m (Tighe and Chamberlain 2009), but up to ±1.5 km by Sobrino *et al*. (2007).

GIS and Archaeology

With the rise of space-borne imaging sensors, remote sensing has now come to encompass a plethora of activities. These activities include the operation of satellite systems, image data acquisition and storage, data processing, data interpretation, and data publication. Computerized geographic information systems (GIS) are one of the means open for processing, interpreting, and publishing data. GIS and satellite remote sensing greatly facilitates the analysis of geographic, geometric, or topological in order to study structures at the human scale (spatial analysis). It was introduced to archaeology in the 1970's and was greatly facilitated by the introduction of GIS in 1990 (White and Surface-Evans 2012; Clarke 1977; Robertson *et al.* 2006; Goodchild and Janelle 2004).

Generally, a GIS is any information system that allows for the creation, acquisition, editing, and storage of geographic information in order to query, analyze, model, and visualize geographical and spatial data. GIS programs, such as AutoCAD, ArcGIS, and GRASS, allow researchers to create interactive queries, edit data in maps, and present the results of these operations (figure 4.2). Spatio-temporal location as the key index variable for GIS processes and any variable that can be located spatially and temporally, can be referenced using a GIS. The units applied to temporal-spatial data vary widely, but all Earth-based spatial–temporal location and extent references are relatable to one another and to a physical location or extent in space–time. Locations or extents in this spatio-temporal matrix are recorded as dates/times of occurrence, and x (longitude), y (latitude), and z (elevation) coordinates. Geographic locations or extents that are defined with coordinates are represented by vectors (points, lines, polygons). Continuous geographic variation, on the other hand, is represented over a grid known as a raster.

Satellite data fall under the category of raster data within GIS (White and Surface-Evans 2012; Clarke 1977; Robertson *et al.* 2006; Goodchild and Janelle 2004).

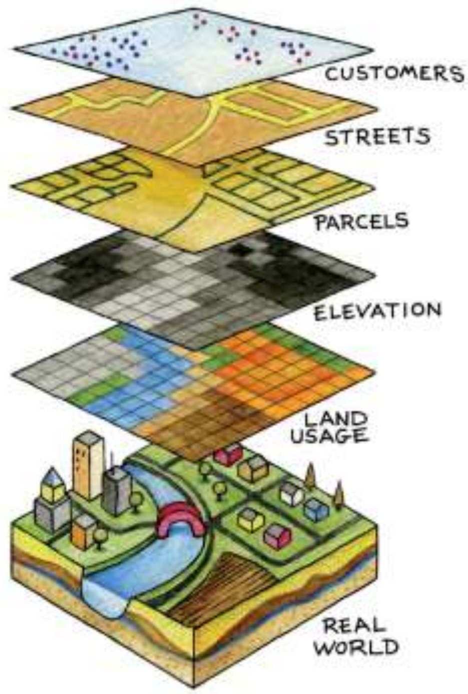


Figure 4.2: Graphical representation of a geographic information system (Stanford Geospatial Center)

The accuracy of GIS is dependent on the source data and how they are encoded and referenced. Main sources for creating a digital topographic database include topographical maps, aerial photography, and satellite imagery. These sources add data to a GIS, as well as identify attributes to be mapped in layers over scale facsimile of a location. While satellite imagery is an already digital format, topographical maps and aerial photography are often non-digital sources that must be scanned into a raster format, and resulting raster data have to be given a theoretical dimension by a warping technology process. This has inherent inaccuracies, like all geographical data, but they are more accurate and precise than conventional map analysis (White and Surface-Evans 2012; Robertson *et al.* 2006; Goodchild and Janelle 2004; Clarke 1977).

The vectors and rasters are simply the first part of a GIS: the representation of the conditions of the earth's surface in the studied area. The second half of a GIS is the functions, algorithms, methods, models, and database design applied to the earth's representation. The variability in how the representations of the earth's surface are manipulated is immense and includes diverse subjects like ecology, urban planning, political sciences, and many more (White and Surface-Evans 2012; Robertson *et al*. 2006; Goodchild and Janelle 2004). To better illustrate the range of problems GIS can address in archaeology, particularly the archaeology of road systems, I will present case studies from the Roman Empire the Inka Empire, and Chaco Canyon.

In 2014, Magli *et al.* investigated the Via Appia of the Roman Empire. The segment of the road running from Collepardo to Terracina is renowned for its straightness, despite being over 61 kilometers. To investigate the historical claims of this road's straightness and elucidate the techniques of ancient surveyors, Magli *et al.* performed high-precision GPS survey and then integrated the survey data with maps and astronomical data in a GIS. According to their calculations, Magli and associated researchers were able to determine that not only is the segment of the Via Appia from Collepardo to Terracina unfailingly straight, but astronomy was used in the construction of the road. Specifically, they were able to determine that the Via Appia was oriented to the setting of the star Castor and the cardinal directions during construction (Magli *et al.* 2014). Through GIS, Magli *et al.* were able to georeferenced their data; an undoubtedly useful function of a GIS, but not the most complex.

On the more complex end of GIS is network analysis. This analysis is based on network theory: the study of complex interacting systems that can be represented as graphs. Social scientists can use network theory to represent social relationships and then analyze through means such as centrality measures. By presenting social relationships in graphical form, it is transformed into data that can be analyzed by a GIS (Jenkins 2001). Jenkins performed such an analysis in his 2001 work on the Inka road system. By mapping the location of storage facilities and administration facilities in the Inka Empire, he was able to measure and identify the interaction of three centrality measures. These centrality measures are degree centrality, closeness centrality, and betweenness centrality. Degree centrality is an index of exchange or communicative activity; closeness centrality measures the relative efficiency with which a center can communicate with any other center; and betweenness centrality provides an index of the potential to control the flow of information or goods from one center to any other center. Vilcashuaman ranks the highest in betweenness centrality, followed by Cuzco, Hatun Xuaxa, Paria, and Raqchi (Jenkins 2001: 667-669).

Jenkins determined that the Inka built their storage facilities and administrative centers at regions of high and low centrality. He supported his argument by also incorporating the structural properties of two different exchange networks (wealth finance and staple finance) of the Inka Empire into his analysis. Wealth finance is defined as the flow of prestige goods throughout the empire while staple finance is the storage and exchange quotidian goods (figure 4.3 and 4.4; Jenkins 2001: 657-661). Due to the confluence of these variables, he was able to determine several things. First, the Inkas built large administration centers and storage facilities at regions of high and low centrality in the highlands. Second, large storage facilities were built without administration centers at regions of low centrality according to the needs of staple finance. And finally, smaller administrative centers with almost no storage capacity were also built in regions of low centrality in order to serve the wealth finance exchange network (Jenkins 2001: 679).

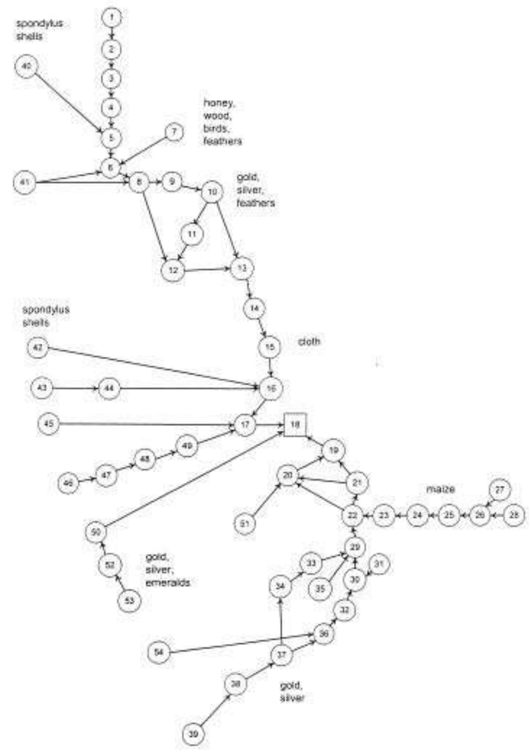


Figure 4.3: Network of staple finance in the Inka Empire (Jenkins 2001)

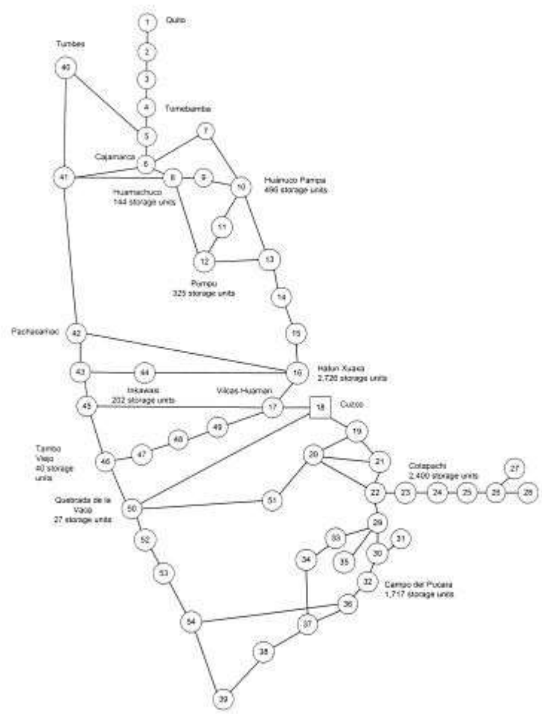


Figure 4.4: Network of wealth finance in the Inka Empire (Jenkins 2001)

The last example of GIS to research roads is Kantner's 1997 LCA to determine the actual function of the Chaco roads: economic, religious, or connectivity. Kantner created a cost-surface using Tobler's hiking or walking speed function and slope in order to find the most time-efficient paths between the settlements of Chaco Canyon. To do this, a Digital Elevation Model (DEM) was brought into a GIS, modified with both a slope and the walking speed function, and then cost distance and cost path values were calculated. The resulting least cost paths (LCP) were then compared to actual Chaco Roads. Kantner found that the majority of the road segments correlated with LCP generated between great houses and habitation clusters; many of the LCP also correlated with no roads but small stone circles that may mark informal paths. From his research, he was able to conclude that most of the roads served to connect settlements, but that each community most likely constructed roadways to serve their own needs (Kantner 1997).

Least Cost Path Analysis (LCA). One of the most common ways to manipulate geographic data in GIS is to perform a Least Cost Path Analysis (LCA), as mentioned earlier in the Kantner example. LCA is based on Zipf's Principle of Least Effort and assumes that humans will economize aspects of their behavior whenever possible. As a result, humans will limit the costs, physical or not, of traveling across a landscape by using all available knowledge to determine the appropriate path. Archaeologists are drawn to this analysis because it formulates hypothetical networks of travel and interaction of ancient cultures. By researching the means of movement for a culture, archaeologists can elucidate economic, political, and social relationships facilitated by travel (White and Surface-Evans 2012: 2; Robertson *et al.* 2006).

LCA answers the straightforward question of what is the most cost-efficient route between Point A and Point B by incorporating directionality, distance, and model algorithms. Cost is calculated using raster data and adds up all the costs of moving across the cells of the grid. The first factor of an LCA, directionality, was ignored in some of the first analyses performed. Previously, LCAs assumed that the cost to move in and out of cell was equally costly, or isotropic. This is not realistic. In the case of the raster representing the elevation of a region, the direction one enters a cell could have high differentials in the cost. For instance, entering the cell from one direction could be travelling downhill and entering from the opposite direction could be travelling uphill. To consider the effort of walking downhill versus walking uphill equal is highly inaccurate. As a result, geospatial analysis has incorporated anisotropic directionality calculations. Distance, the second consideration in a LCA, is the easiest to understand. Distance accumulation in either two or three dimensions can quickly increase the cost of movement; however it is often secondary. In the case of steep elevation changes, a longer path that avoids steep slopes is typically more cost-effective than a more direct route (figure 4.5; White and Surface-Evans 2012: 2-4; Robertson *et al.* 2006). However, the final decision in whether the more direct route or the longer one is the most cost-efficient ultimately depends on the motivations of the traveler, which can be difficult to determine in the archaeological record.

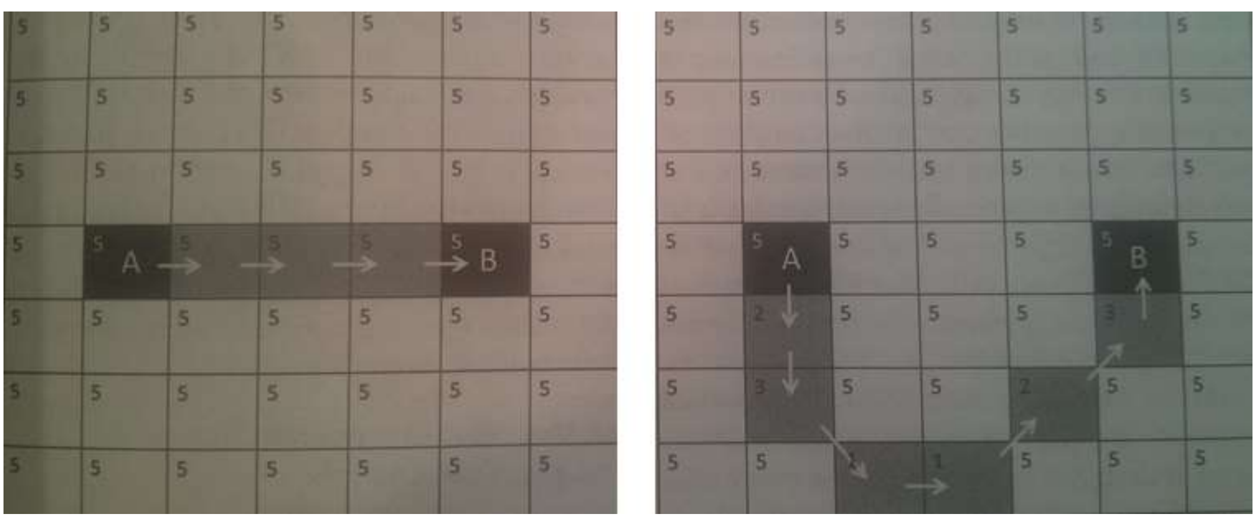


Figure 4.5: Isotropic (left) versus anisotropic (right) directionality grids also representing a longer path that is more cost-effective than a direct route (White and Surface-Evans 2012)

Model algorithms are often incorporated into LCA to handle such difficulties as differential cell costs, barriers to travel, and accurately modeling human movement. The most common algorithms are Dijkstra and A*. Dijkstra was designed to find the lowest cost path between the origin and destination and discard all alternative paths. It is a brute force algorithm and does not take into account mitigating factor like accumulated travel distance. A* on the other hand was designed as an extension of Dijkstra. A* uses a distance-plus-cost heuristic function to improve its search for the lowest cost route. The algorithm also maintains a list of alternative routes and will change paths if the current one becomes less efficient. Dijkstra brute force approach allows it to calculate LCAs between multiple destinations but the intricacy of A* is better suited for one pair of origins and destinations. A*'s heuristic function also allows cost estimation of travelling to intermediate points while Dijkstra only provides the total cost of the trip. Dijkstra is the standard for archaeology research and comes embedded in all GIS software. It is also the slower method but guarantees the calculation of the least cost path. A* is faster, but less accurate. A* is rarely used in archaeology but its calculations of alternative paths holds potential (White and Surface-Evans 2012: 2-4; Robertson *et al.* 2006).

A creation of a LCA requires yet another step before completion, though: modeling considerations. These considerations are the variables, data, and measure of cost. When performing a LCA archaeologists usually incorporate environmental, cultural, and physiological variables to improve the accuracy of their work. Environmental variables would be topography, hydrology, vegetation, and animal migrations. Cultural would be territorial boundaries, settlements, and ritual spaces. Physiological considerations are sometimes taken into account by applying caloric expenditure or walking speed to the analysis. All desired variables are chosen and combined by the archaeologist to create a cost-distance layer. However, before a cost-distance layer can be made an archaeologist must have the necessary cultural and environmental data. Archaeologists interested in LCA must gather settlement and land-use data from previous investigations to fulfill their need for cultural data. For environmental data, archaeologists usually rely on remote sensing by satellites and publicly available rasters of satellite data, such as DEMs. Once an archaeologist has data, it is necessary to identify how cost is measured. The most basic measure of cost is cumulative distance. This is often equated with the second method which is travel time, but this is not always the case. The third and final way to measure cost is through calorie expenditure. Energetic expenditure is rarely the equivalent to time and distance measures, especially in cases of dramatic topography. It is up to the archaeologist to take into consideration the culture he or she is researching and determine the measure or measures of cost to be used in their analysis (White and Surface-Evans 2012: 4-6; Robertson *et al.* 2006). All sources of data are then combined in a GIS to create a cost layer which is then used to create the cost distance layer and eventual LCP (figure 4.6).

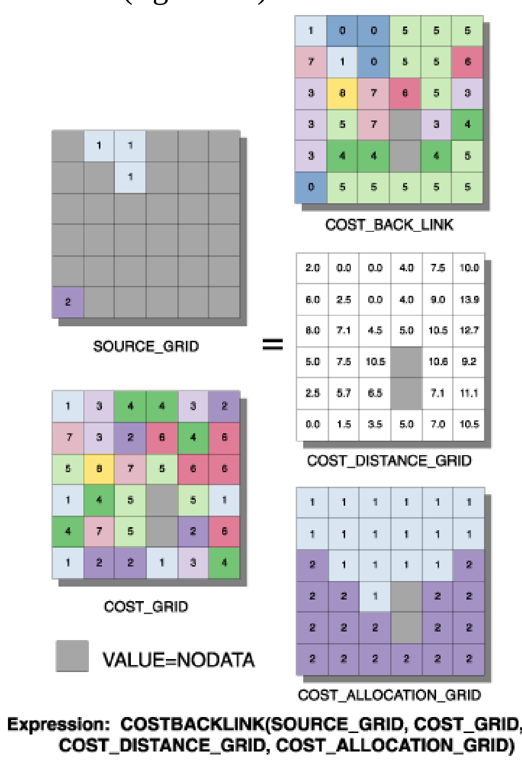


Figure 4.6: Illustration of layers necessary to create a LCA (Esri 2011)

The current trend of LCA in archaeology is to perform multi-variate analysis. White and Howey have both written thorough papers describing the use of multi-variate LCA in their research (2012; 2007). White's research on prehistoric trail networks in the Western Papaguería of the North American Southwest incorporates the use of topography, energy expenditure, archaeological sites, sacred places, water sources, and raw material deposits to create a multi-faceted LCA. Through his research, White was able to challenge the previously held belief that the trails of Western Papaguería were used mainly for long-distance travel and instead argued that their main purpose was to enable the daily movements of the region's permanent residents (2012). Howey's work, performed prior to White's, integrates the criteria of slope, hydrology, and vegetation cover to research inter-tribal relationships in Late-Prehistoric Michigan. She found that the predicted roads allowed for access to culturally significant features, such as the Missaukee earthworks, and were thus a decent approximation of past patterns of movement (2007). However, she was unsatisfied with the singular suggested route provided by a traditional LCA and in 2011 successfully improved her LCA of the region with an adaptation of electrical Circuit Theory (Howey 2011).

The use of remote sensing in Peru has proven immensely useful as archaeological sites are often difficult to reach due to terrain and infrastructure, and as a result GIS has become a popular means of researching the relationships between past Andean cultures and their environment (Parcak 2009: 17). In the Andes, GIS has been used to identify survey areas and research the relationship between large networks of sites. For example, Stanish *et al.* performed an intensive settlement survey in the southwestern Titicaca Basin in order to assess the nature of long-distance trade of Tiwanaku and its primary colony of Moquegua. The survey area was chosen based on the results of a LCA and supported by informant data about the historic location of caravan routes. Through Stanish *et al.*'s research, they uncovered almost continuous evidence of Tiwanaku occupation along the trails and roads between Tiwanaku and Moquegua. They also determined that, unlike the Inka, Tiwanaku did not maintain way stations or develop a formal road system and instead relied on camelid caravans that required a low-cost path to travel (Stanish *et al.* 2010).

Rademaker *et al.* provide another instance of LCA used to identify a survey course, this time in Southern Highland Peru. In their research, they performed several LCA with energy-based cost surfaces built off of slope and estimated walking speed. They then surveyed a predicted least cost corridor connecting the Paleoindian site of Quebrada Jaguay on the Pacific Coast with the Alca obsidian source. During the survey, Rademaker *et al.* discovered multiple highland open-air and rockshelter sites containing coastal lithic materials and diagnostic projectile points dating from the Late Glacial and Early Holocene. They determined that LCA is a useful method in predicting archaeological survey areas in the Andes, particularly for hunter-gatherers as their movements are typically based on economic efficiency (Rademaker *et al.* 2012).

5. *EXPERIMENTS WITH LEAST COST PATH ANALYSIS*

Least Cost Path Analysis has proven useful in recent archaeological work for researching informal path networks and identifying survey areas remotely. Even Kantner found that LCA identified the smaller paths in the Chaco region better than the large Chaco roads. With my research I used LCA to argue that the goal of construction for the Inka roads was not efficiency of movement, but rather to connect settlements necessary for maintaining their imperial hegemonic administration. The methodology used has some weaknesses that I will seek to improve on in the future, but ultimately I believe I was successful.

METHODOLOGY

Finding the Road from Cuzco to Vilcashuaman

Before performing any kind of analysis, I needed to identify the physical location of the Chinchaysuyu road between Cuzco and Vilcashuaman, or that of a proxy. Cieza de Leon's description of his travels proved immensely helpful in this regard. During his travels, Cieza describes the cities of Guamanga (also known as Ayacucho), Uranmarca, Curahuasi, and Limatambo and crossing the Rios Pampas, Abancay, and Apurimac (Gutierrez 2015 personal communication; Cieza de Leon 2010: 313-322). The accounts of Spanish conquistadores corroborate some of these landmarks.

Today, most of these cities and river crossings lie along the path of the modern Peruvian road Pe-3s. In the case of the Rio Apurimac crossing, the rope bridge that was maintained since the time of the Inka can be seen crossing the river parallel to the modern bridge on satellite images (figure 5.1). As a result, I used Pe-3s to model most of the Chinchaysuyu road between Cuzco and Vilcashuaman. However, Pe-3s does not connect to Vilcashuaman and

Figure 5.1: Modern and rope bridge over Rio Apurimac (Google Earth Pro)

instead turns north at the town Nueva Esperanza to reach the city of Ayacucho. At this juncture, I approximated the Inka road in question by the local roads AY 104 and AY-105. Along this road lies the town of Uranmarca and the Rio Pampas crossing; the presence of these sites justifies my use of this road as a proxy for the westernmost portion of the Cuzco to Vilcashuaman Chinchaysuyu road. Once I combined these two roads, I confirmed the accuracy of the proxy by comparing the cities present along the road to those reported by Julien in her research on the same road segment (figure 5.2). The two matched, and I prepared the proxy for analysis. I hypothesize that LCA will not be able to calculate an accurate prediction of the path of this portion of the Chinchaysuyu road due to cultural, historical, and geographic particularities associated with construction of different segments of the road system according to the needs of the imperial hegemonic administration of the Inka. There are preserved sections of the original road; but due to my inability to survive the region in question, I deemed a proxy to be necessary for the sake of my analysis.

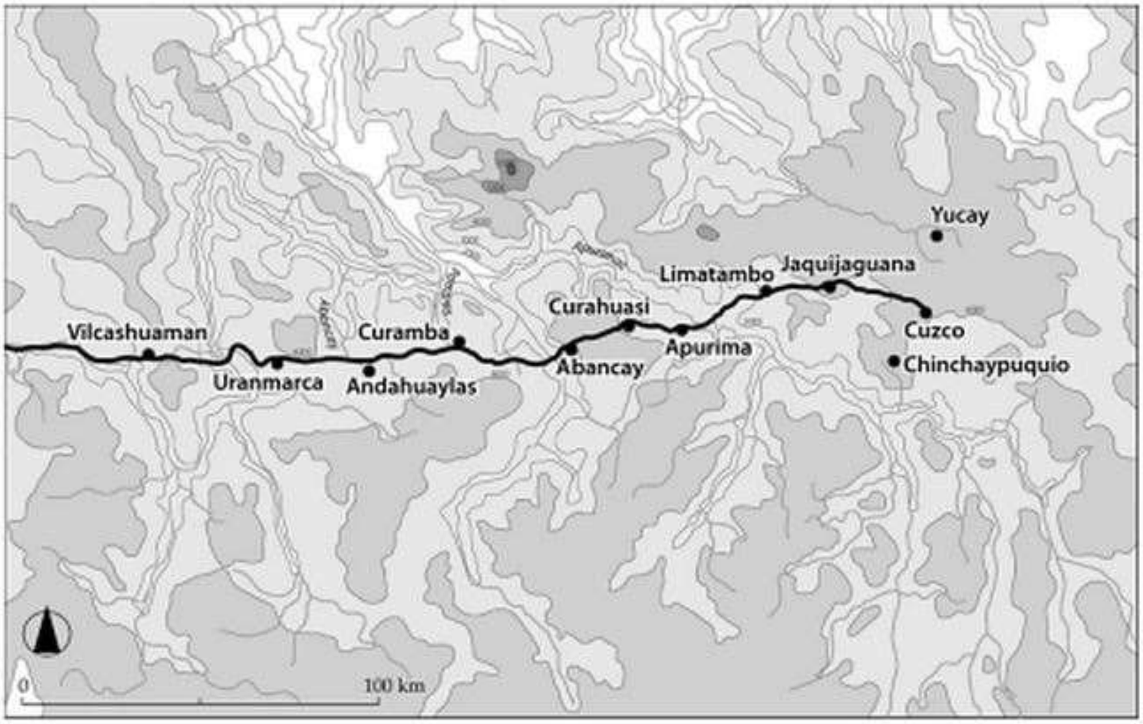


Figure 5.2: Chinchaysuyu Road from Cuzco to Vilcashuaman (Julien 2012)

Criteria Selection

I ran all analyses for this thesis with the program ArcGIS 10.2.2 by Esri. One of the best known programs of its kind, ArcGIS allows for creating and using maps; compiling geographic data; analyzing mapped information; sharing and modifying geographic information; and managing geographic information in a database. The version I used, 10.2.2, is the most recent version of ArcGIS.

I acquired the elevation dataset for my analyses from the ASTER mission digital elevation models (DEM) found on the USGS Earth Explorer website. As discussed earlier, SRTM data have smaller measures of uncertainty and vertical bias; however, the SRTM data of this region were collected over a period of time with greater cloud cover than the ASTER data. As a result, the ASTER data represent the most complete dataset and I used them for this thesis. The ASTER data I gathered have a resolution of 1 arc-second; they are of comparable resolution to the SRTM. Water features, cities, and roads were added to the DEM to complete the dataset. Water feature data were gathered from the open-source website DivaGIS. Data on the geographic locations of cities and the proxy road were collected from Gaia GPS and Google Earth Pro.

I determined which data to use by the variables I chose for the analyses. The dependent variables of the analyses were slope, distance from water, and caloric expenditure. Slope is the standard variable when creating a LCA; however, I chose the others to make more complex analyses. I used distance from water because most towns in the Andes are located near rivers and streams due to the arid nature of the environment. Thus, traveling away from water should be less efficient and also limit likely routes of travel to areas around cities. I added caloric expenditure to the analyses to determine if the location of the road was determined by energetically efficient travel, or for other reasons, such as connectivity of sites. I then compared the LCAs created with the dependent variables to the independent variable: location of cities. I chose location of cities as an independent variable as it is a good proxy for the location of the road and provides the necessary amount of data points need to conduct a near analysis in ArcGIS. I conducted seven LCA for this thesis. The first four were single variable analyses in order to determine which variable predicts the path of the Chinchaysuyu road from Cuzco to Vilcashuaman best. I then combined these variables to determine if a confluence of these variables improves the predictive properties of the LCAs.

Slope. The first LCA I completed for this thesis was the simplest with only a variable of slope added. Slope is a good baseline for determining ease of travel and was used as a foundation for all following analyses. In order to perform this analysis, the slope was calculated using percent rise and then reclassified to a scale of 10. Reclassifying the data allows for easier data manipulation and comparison with other datasets. The reclassified data were then used to create a cost distance surface to measure the cost of travel as one moves away from the destination of Vilcashuaman. This surface was then applied to a cost path function which created a LCP between Cuzco and Vilcashuaman (figure 5.3). This LCA suggests that the road could have been much straighter than it currently is. However, I used percent rise to calculate this LCP. Another option would have been to use degree slope which may have resulted in a different LCP.

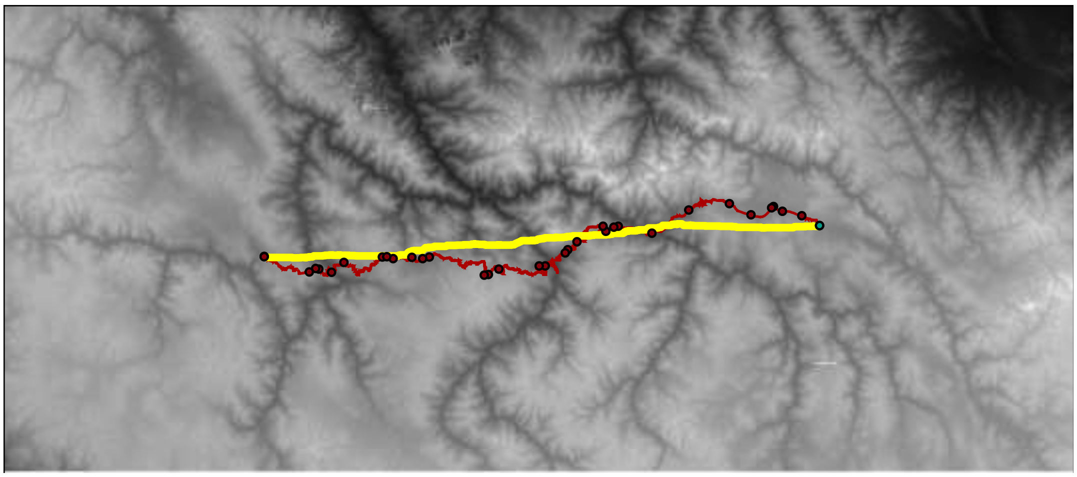


Figure 5.3: LCP with the variable of slope. LCP shown in yellow, road shown in red.

Water. The second LCA was performed using distance from water. To do this, the Euclidean distance function was used and then reclassified to the same scale as the slope cost surface calculated earlier. A cost distance and cost path function were performed (figure 5.4). This LCP follows the road almost perfectly up until the crossing of the Rio Apurimac. As the Inka Empire spread northwest from Cuzco during its nascence, it is possible the cities leading up to the Rio Apurimac were influenced by ecological variables and that the cities founded later on were built solely for cultural factors. Water also has a strong ritual component in Inka culture, and this was likely a strong cultural influence on the location of the cities prior to the Rio Apurimac crossing (Bray 2013).

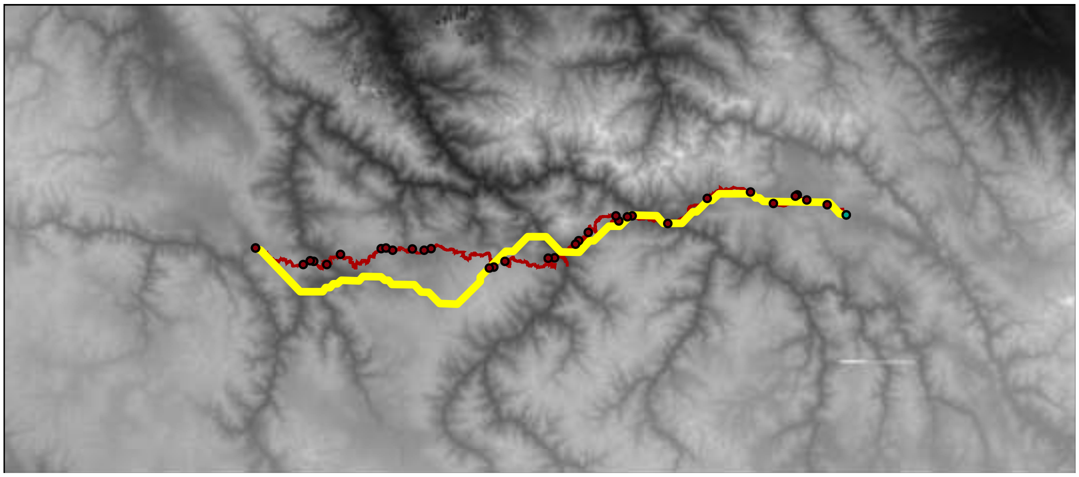


Figure 5.4: LCP with the variable of distance from water. LCP shown in yellow, road shown in red.

Caloric expenditure and Slope. I performed the next two LCA's after adding the variable of caloric expenditures to the slope cost surface. Pandolf, Givoni, and Goldman (1977: 578) developed the best working formula for calculating energy expenditure for the United States Army Research Institute of Environmental Medicine based on the weight of the traveler, the weight they are carrying, speed they are walking, terrain, and steepness of the terrain. However, their equation loses its accuracy when travelers do not walk on level ground or solely uphill (Branting 2004: 76, White 2012: 194). Walking downhill causes the equation to produce negative cost estimates, which suggests energy is gained by walking downhill. This is obviously impossible; downhill travel still requires effort.

Santee *et al*. (2001) proposed a modification to the Pandolf equation to ameliorate this inaccuracy. Their model operates on the assumption that the initial reduction in the energy cost of downhill travel is due to gravity, but also the action of muscles and joints (White 2012: 194-195). For these reasons, this equation was used to calculate caloric expenditures. When this is the case, energy expenditure is calculated as:

$$M_{watts} = 1.5W + 2.0(W + L)\left(\frac{L}{W}\right)^2 + \eta(W + L)(1.5V^2 + 0.35VG) - \eta\left(\frac{VG(W+L)}{3.5} - \frac{(W+L)(G+6)^2}{W}\right)$$

Where

M_{watts} = metabolic rate, in watts
W = subject weight, in kilograms
L = external load, in kilograms
V = walking speed, in meters per second
G = slope, in percent
η = terrain coefficient

I added this equation to the GIS using the map algebra function to modify the slope cost surface. A single terrain coefficient was selected based on the terrain coefficient categories developed by Soule and Goldman in 1972. The chosen terrain coefficient is for dirt roads, η=1.0, as this is the closest descriptor to the Inka roads. I drew the average weight from Ferris and Nelson (1916) and Frisancho and Baker (1970). According to these sources, the average weight of a Quechua man between the age of 15 and 35 is 48.8 kg (figure 5.5). Unfortunately, this weight is from older sources and may not be accurate anymore. However, I believe it is a serviceable estimate for constant of weight in the Pandolf-Santee equation as modern Quechua identify themselves as descendants of the Inka and peasant men in Tawantisuyu started work between the ages of 12-18 (D'Altroy 2015: 296; Rowe 1958: 514-516).

To estimate external load, I used the weights reported by Malville (1999) during her research on the porters of eastern Nepal. Physiologically, these porters are similar to the Quechua people, use similar technology to carry their burdens (tumplines), live at similar altitudes, and travel similar distances. Malville reports the average weight of loads carried by eastern Nepali porters to be 73 kg. I used this figure for one LCA, however, I ran another LCA using external loads of 5 kilograms. With these two values, I hope to capture the path ArcGIS calculates for a mit'a laborer consigned to performing portage (73 kg) and an imperial messenger who would have forgone the burden of supplies for the sake of speed. A consideration that I may take into account for later research is the practice of *tokma*, the habit of Nepali porters to walk short distances and then rest when carrying heavy loads. In this manner, Nepali porters are able to walk ten kilometers a day while carrying loads one and a half times greater than their body weight. This speed would be roughly 0.28 m/s, assuming they walked a kilometer an hour (Malville 1999).

Age	N	Stature		Weight		Sitting height	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
			Males				
2.11	8	80.4	5.2	10.0	1.9	48.5	3.4
3.37	7	86.3	5.4	11.6	1.6	51.7	3.2
4.19	13	91.4	5.8	13.6	1.5	54.2	2.8
5.27	11	95.6	4.7	14.1	2.0	56.2	3.5
6.19	23	106.2	4.7	20.0	3.8	59.1	8.7
7.11	36	115.6	4.9	21.7	3.1	64.3	4.3
8.30	40	116.4	5.7	22.7	3.4	65.2	3.3
9.25	48	119.6	6.0	24.4	3.6	66.7	3.8
10.27	49	122.7	5.2	26.3	3.5	67.8	4.0
11.29	51	127.7	7.2	28.5	4.6	68.9	3.8
12.23	68	130.3	6.2	30.1	4.1	70.3	3.4
13.28	59	134.8	6.4	32.7	4.0	72.3	3.8
14.22	43	139.5	7.4	35.3	4.7	74.4	3.7
15.31	46	145.6	7.2	39.8	3.5	77.5	5.3
16.30	46	148.2	7.9	42.5	4.0	79.3	4.4
17.24	40	150.3	7.0	45.9	4.5	80.5	5.0
18.24	29	155.3	7.5	49.0	4.9	82.7	5.3
19.35	21	156.7	4.7	50.0	4.8	84.2	2.6
20.15	17	157.1	4.9	50.0	4.9	84.7	2.9
21.31	20	159.9	4.7	52.8	5.6	84.2	4.0
22.35	30	160.3	4.8	53.8	5.9	84.8	4.0
35.00	50	160.0	4.9	55.9	6.5	84.5	6.0
			Females				
2.13	7	79.3	5.8	9.7	2.0	47.8	3.2
3.00	7	85.5	5.5	11.3	2.3	52.2	2.9
4.15	12	90.7	5.2	12.8	1.6	54.2	2.5
5.07	13	96.3	8.2	13.8	1.7	55.3	3.4
6.19	26	105.1	5.4	17.5	1.8	60.4	2.7
7.02	29	110.9	8.5	20.9	6.2	62.7	4.4
8.14	41	114.9	6.3	22.1	4.1	65.0	3.5
9.07	30	119.8	5.1	22.4	2.7	67.2	7.2
10.22	35	124.6	6.8	25.8	3.7	69.9	5.4
11.33	33	129.4	6.4	28.1	5.1	71.5	3.9
12.23	34	132.0	6.1	30.8	5.5	72.7	3.2
13.19	30	136.9	6.0	34.4	5.5	74.3	3.5
14.24	25	140.4	5.3	39.5	6.7	76.4	4.7
15.00	20	141.6	5.1	42.9	5.6	77.8	2.8
16.19	15	143.6	6.0	43.9	7.3	79.0	3.6
17.04	10	148.4	4.3	50.9	8.0	81.9	2.2
18.16	10	147.7	6.5	48.2	5.9	80.6	3.3
19.06	12	149.6	3.7	53.6	3.5	82.6	2.9
20.58	12	148.6	6.7	50.2	7.3	80.2	3.4
21.50	27	148.2	5.2	50.0	1.4	81.0	3.1
22.30	36	148.2	4.8	50.2	6.2	80.0	9.7
35.00	50	148.0	5.2	54.0	6.5	80.0	6.3

Figure 5.5: Anthropometric measurements of cross-sectional sample of Quechua people from Nuñoa district (Frisancho and Baker 1970)

I gathered the walking speeds of the LCAs from multiple physiological walking experiments done by McDonald; Soule and Goldman; Pandolf *et al*.; and Santee *et al*. (1961; 1972; 1977; 2001). They determined possible walking speeds ranged from 0.69 m/s (rarely reached under normal conditions) to 2.4 m/s (efficiency of walking becomes less than running);

1.3 m/s was determined to be the least cost walking speed. Drawing from their research, the 5 kg external load LCP was run at 2.4 m/s and the 73 kg external load LCP was run at 0.69 m/s. Both of these cost surface layers were reclassed and used in cost distance and cost path functions to create a “high speed-low weight” LCA (figure 5.6) and a “low speed-high weight” LCA (figure 5.7).

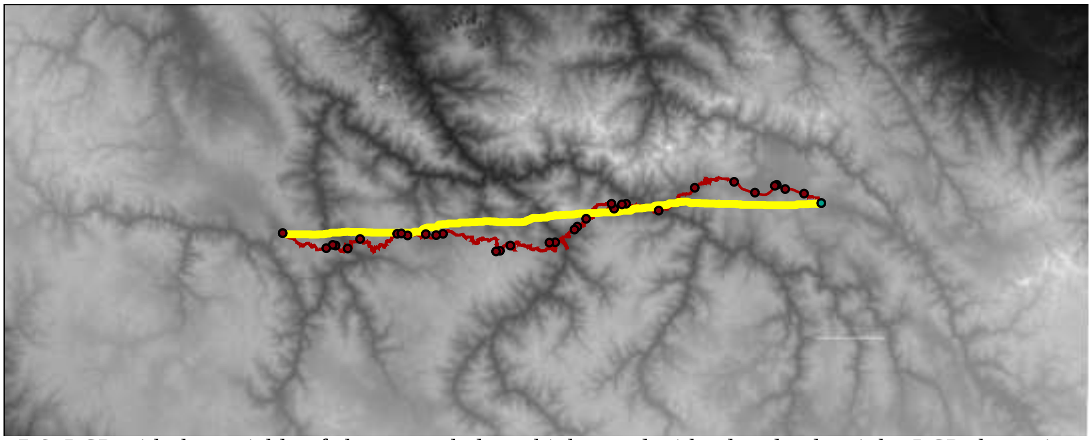


Figure 5.6: LCP with the variable of slope traveled at a high speed with a low load weight. LCP shown in yellow, road shown in red

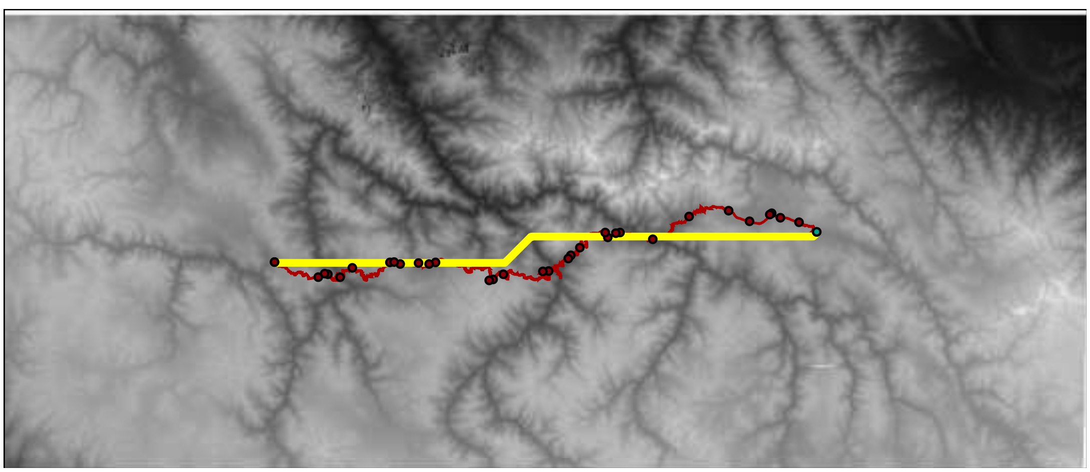


Figure 5.7: LCP with the variable of slope traveled at a low speed with a high load weight. LCP shown in yellow, road shown in red.

Slope and Distance from Water. I then added distance from water to the slope variable in the third to last LCA to see if it improved the predictive powers of the LCA. I combined the reclassed slope and water cost surfaces I created earlier together through the weighted overlay function. The weighted overlay function then created a single cost surface raster that was used to calculate a cost distance surface and a subsequent cost path (figure 5.8). With this analysis, I was able to illustrate that slope was not a large factor when the Inka road was built. The distance from water illustrates that at least a quarter of the road relates to the location of major waterways. In this analysis, slope actually dragged the LCP far from the physical location of the road.

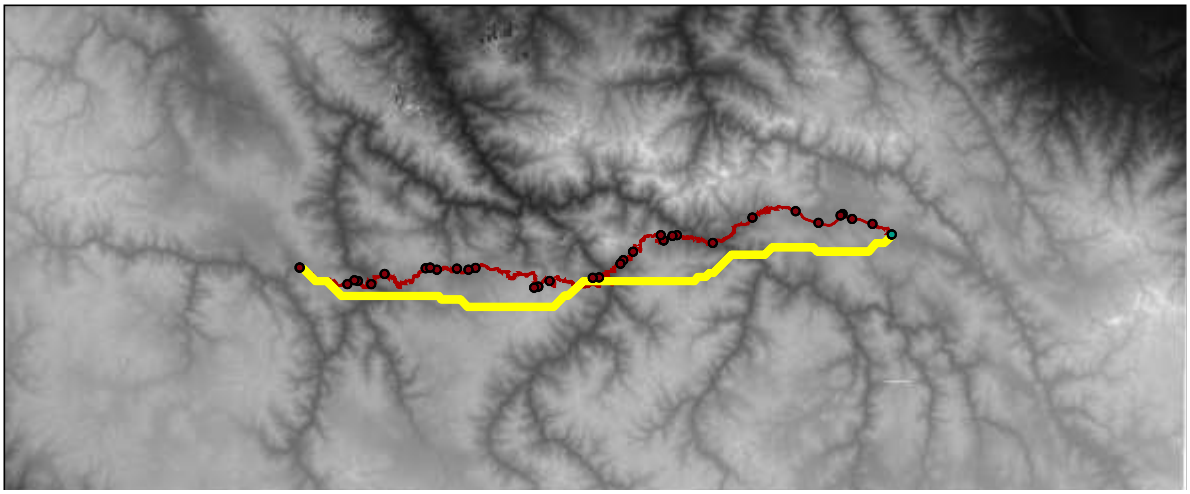


Figure 5.8: LCP with the variables of slope and distance from water. LCP shown in yellow, road shown in red.

Slope, Caloric Expenditure, and Distance from Water. The last two LCAs combine slope, water, and caloric expenditure. The first one combined the reclassed cost surfaces of slope with high speed-low weight caloric expenditure and distance from water into a weighted overlay to create a LCP (figure 5.9). I created the second one in the same way, but with the slope with low speed-high weight caloric expenditure cost surface (figure 5.10). I performed these analyses to argue more effectively for the influence of cultural centers on the location of the road. The second analysis mirrors the location of the road up until the Rio Apurimac, similar to the distance from water LCA. I think this might illustrate a change in the pattern of Inka settlement planning over time.

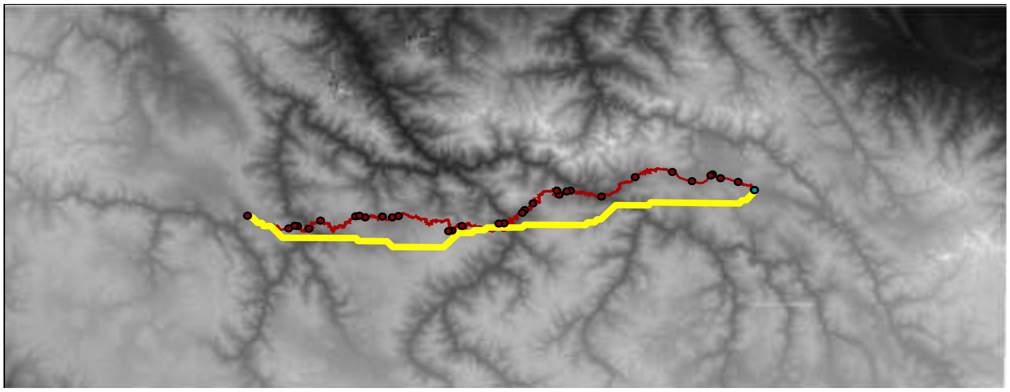


Figure 5.9: LCP with the variables of slope and distance from water traveled at a high speed with low carry weight. LCP shown in yellow, road shown in red.

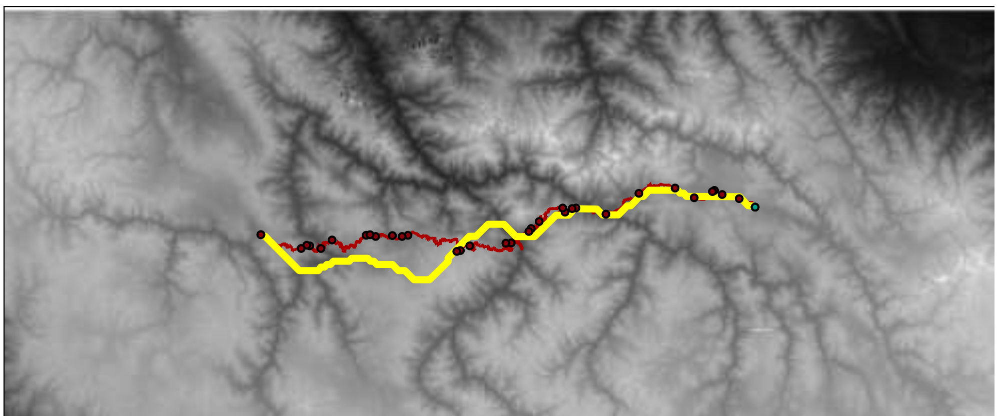


Figure 5.10: LCP with the variables of slope and distance from water traveled at a low speed with high carry weight. LCP shown in yellow, road shown in red.

ANALYSIS OF RESULTS

In order to determine the degree of difference between the LCPs created and the actual path of the Chinchaysuyu road from Cuzco to Vilcashuaman, I performed a near analysis. Near analysis functions by calculating the shortest separation between any two features. This can be done between any kinds of features saved in vector format. For this research, I used near analysis between the location of the cities and each LCP. I chose to use location for cities instead of the actual road in order to obtain a larger sample size. When I ran a near analysis between two line features, such as the portion of the road I researched and the LCP, only one data point was calculated: the point where they were closest. As all the LCP crossed the actual road at least once, this led to all LCAs having an average distance of zero. By using the location of cities as a proxy for the road, I was able to obtain thirty-one points of comparison between the LCP and the Chinchaysuyu road and calculate a more accurate average distance. I excluded Cuzco and Vilcashuaman from the comparison sample because all LCP began and ended at these points.

After performing a near analysis on each LCP, I calculated the average distance from cities along the road (figure 5.11). As a comparison, I also calculated the average distance of cities from the actual Cuzco to Vilcashuaman portion of the Chinchaysuyu road. This value was calculated to be 0.0009 meters from the road. After obtaining the average distances, I ran a Wilcoxon signed ranks test in JMP to compare the average distances from cities for each LCA to the average distance of cities from the Chinchaysuyu road. I used Wilcoxon signed ranks test because not all sets of distance data were parametrically normal. The results of the Wilcoxon signed ranks tests indicate that none of the performed LCAs created a LCP that accurately predicted the physical location of the Chinchaysuyu road between Cuzco and Vilcashuaman (figure 5.12). In fact, the results show that the LCPs created are undeniably deviant from the actual path of this road. However, these results hide the fact that two LCPs matched the physical location of the road almost exactly until the Rio Apurimac Crossing. These two LCAs, distance from water and slope and distance from water traveled at a low speed with high load weight, have the lowest average distances, though.

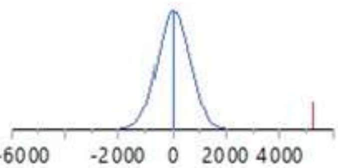
Least Cost Analysis	Average Distance (m)
Slope	5217.58
Distance from water	4764.76
Slope traveled at a high speed with low load weight	9094.56
Slope traveled at a low speed with high load weight	4917.4
Slope and distance from water	5217.51
Slope and distance from water traveled at a high speed with low load weight	8785.21
Slope and distance from water traveled at a low speed with high load weight	4394.17

Figure 5.11: Average distances of cities from all LCPs created

Wilcoxon Signed-Ranks for Slope LCA

Hypothesized Value	0.0009
Actual Estimate	5217.58
DF	30
Std Dev	3253.82

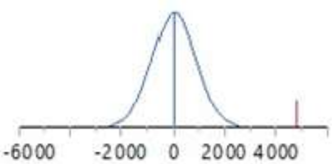
	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001
Prob > t	<.0001
Prob < t	1.0000



Wilcoxon Signed Ranks for Distance from Water LCA

Hypothesized Value	0.0009
Actual Estimate	4764.76
DF	30
Std Dev	4551.33

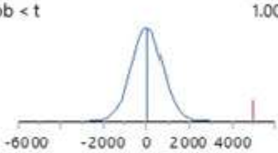
	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000



Wilcoxon Signed Ranks for Slope Traveled at a Low Speed with a Heavy Load Weight LCA

Hypothesized Value	0.0009
Actual Estimate	4917.4
DF	30
Std Dev	3910.29

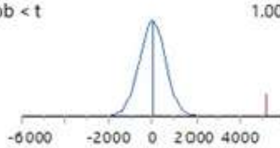
	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000



Wilcoxon Signed Ranks for Slope Traveled at a High Speed with a Low Load Weight LCA

Hypothesized Value	0.0009
Actual Estimate	5217.51
DF	30
Std Dev	3253.97

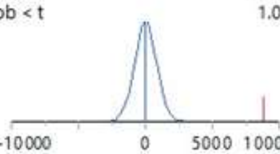
	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000



Wilcoxon Signed Ranks for Slope and Distance from Water Traveled at a High Speed with a Low Load Weight LCA

Hypothesized Value	0.0009
Actual Estimate	8785.21
DF	30
Std Dev	4394.17

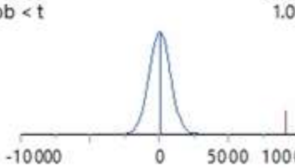
	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000



Wilcoxon Signed Ranks for Slope and Distance from Water LCA

Hypothesized Value	0.0009
Actual Estimate	9094.56
DF	30
Std Dev	4126.23

	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000



Wilcoxon Signed Ranks for Slope and Distance from Water Traveled at a Low-Speed with a High Weight LCA

Hypothesized Value	0.0009
Actual Estimate	4742.59
DF	30
Std Dev	4418.63

	Signed-Rank
Test Statistic	248.0000
Prob > |t|	<.0001*
Prob > t	<.0001*
Prob < t	1.0000

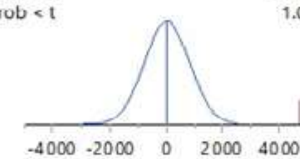


Figure 5.12: Results of Wilcoxon Signed Ranks Test for all LCAs

However, there are some inaccuracies with this study. The first of which is my use of cities as a proxy for the road in the near and subsequent statistical analyses. The road between Cuzco and Vilcashuaman is much more variable than the location of the cities. This is well-illustrated by a LCA performed using only distance from cities as a variable of cost (figure 5.13). When I performed a near analysis on this LCP, I calculated an average distance of zero between the LCP and the cities. However, it is clearly not a perfect prediction of the physical location of the road. Unfortunately, the limitations of the near analysis function necessitates this inaccuracy.

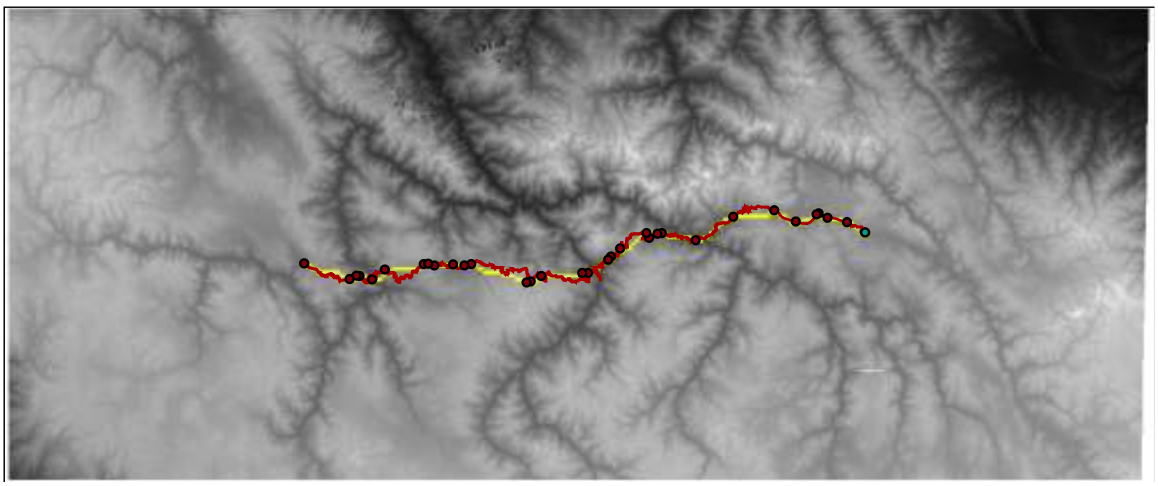


Figure 5.13: LCP with the variable of distance from cities. LCP shown in yellow, road shown in red.

Other inaccuracies of this study are due to imperfections with the use of LCA as a predictive tool for formal roads. The first of these is the inability of LCA to take into account effort saving technology in road building. The Inka had at least three methods for improving the efficiency of travel across the difficult terrain of the Andes: ramps, switchbacks, and steps. Ramp-like roads were utilized by the Inka to traverse small slopes that were less than 10˚. When the slope of a road was greater than 10˚, switchback and/or steps were used. The switchback alleviated the cost of travel on steep slopes by decreasing the gradient while prolonging the distance traveled. Steps on the other hand, ease travel by supplying a flat base for the foot while ascending or descending a slope (Hyslop 1984: 237-239). While Inka roads were able to incorporate all this technology to improve travel conditions, LCA cannot calculate them. Instead, LCA seeks out the shortest, least-costly route between two points; as illustrated by the inconsistencies between the LCP represented in figure 5.13 and the actual path of the road. However, the LCP in the above figure is very close to the physical location of the road; it would be possible to use LCA to identify survey areas when attempting to locate unmapped or informal Inka roads, as long as the cities along the road are known.

In addition, the variable of caloric expenditure when an individual is traveling at a low-speed is not entirely accurate. When moving large amounts of goods, the Inka most often employed a camelid caravan system instead of singular porters (Stanish *et al.* 2010; D'Altroy 2015: 44-45). It would be interesting to create a LCA using the energy expenditure used by a heavily-laden camelid caravan; however, the Pandolf-Santee equations have not been modified for camelids, or even any form of non-human mammal.

A weakness of this study that can be amended without waiting for technological enhancements is the incapacity of LCA to calculate secondary routes, such as bifurcations or trifurcations in the road. LCA is limited to calculating the singular most efficient route as determined by the algorithms used to modify it. In the case of the Cuzco to Vilcashuaman portion of the Chinchaysuyu road, there is at least one bifurcation near the crossing of the Rio Pampas. The river can be crossed at Uranmarca or between Orcos and Chincheros. The second crossing and the trail leading up to it were most likely of Wari origin but both were used through the Inka Empire and onward (Bauer 2006: 484; Schreiber 1992: 160). Circuit theory can be used to circumvent this limitation. Originally introduced to LCA by biological conservationists and landscape ecologists, circuit theory was applied to archaeology in 2011 by Howey in her research on the Missaukee Earthworks. In the case of this research, circuit theory may be helpful in identifying the location of the badly eroded trail to the Orcos-Chincheros crossing of the Rio Pampas due to its creation of a network of overlapping paths instead of the single most economic path.

Another improvement I would add to this methodology for future research was to determine if the segments road between each of the cities along this portion of the Chinchaysuyu road were similar to a calculated LCP. The implementation of the A* algorithm instead of Dijkstra would facilitate this kind of analysis. As for spatial statistics, near analysis may not be the best solution, for the reasons detailed earlier. Regardless, it would be interesting if by breaking the road into segments leads to an improvement in the predictive properties of the LCAs performed.

CONCLUSIONS

The LCAs I performed for this thesis illustrate that the location of Inka roads was influenced by cultural factors, as seen by the similarity between an LCA with the variable of distance from cities and the actual road. The LCP calculated during that LCA was still an imperfect fit, however, its substantial similarity is telling about the construction of the roads. First and foremost, it answers the question of whether the road was constructed first and settlements built around it, or if the road was built to connect settlements. The answer seems obvious, the road was built to connect the settlements, but it belies a more complex chronology. The Chinchaysuyu road was the first road constructed by the nascent Inka Empire after conquering the Chankas and other surrounding ethnic groups. As a result of the short-lived nature of the Empire and the early construction of this road, it can be inferred that the cities along the Chinchaysuyu road date to before the Inka Empire and possibly before the development of the Inka culture.

The role of the roads to connect the settlements also supports the hypothesis that the construction of the Inka road system, particularly this segment, were determined by cultural, historical, and ecological particularities associated with construction of different segments of the road system according to the needs of the imperial hegemonic administration of the Inka. The needs of imperial hegemonic administration of the Inka included moving specialized laborers (kamyuqkuna, ayllakuna, and yanakuna), political colonists (mitmaqkuna), and resources collected via the mit'a labor tax throughout the Empire. Thus, there are large Inka urban centers such as Guamanga (Ayacucho), Uranmarca, Curahuasi, Limatambo, Abancay, and Apurimac along the road (Cieza de Leon 2010: 313-322). Limatambo, Tamburco, Sandor are most likely sites of tampus, another crucial component of Inka imperial administration. Further, Vilcashuaman was a site founded for the purpose of Inka administration of the newly conquered Chanka territory. As an administrative center, it was well-stocked and had about seven hundred storehouses located around the city. Vilcashuaman was more than just an administrative capital, it was considered the geographic center of the Empire and had the greatest potential to control the flow of information or goods from one administrative center to any other center (Cieza de Leon 2010; Jenkins 2001). These cultural and historical particularities are witnessed in the course of the Chinchaysuyu road which is northbound but was diverted westward to run through Vilcashuaman. Currently, Vilcashuaman is of less cultural influence than it was in the Inka Empire. The main north-south road Pe-3s from Cuzco leads to Ayacucho and bypasses Vilcashuaman. Vilcashuaman was not even connected to Pe-3s via AY-104 and AY-105 until the 1970's (Heilman 2010: 136).

By routing the road to run through places of cultural and historical significance, the Inka also encountered geographic difficulties such as rough terrain and river crossings. LCA does not take into account the technologies the Inka had to facilitate travel across theses geographic particularities. These technologies include the advanced rope bridges constructed by the Inka; as well as road construction techniques for easing travel across steep slopes with ramp-building, switchbacks, and steps (Bauer 2006; Hyslop 1984). This represents a significant weakness of LCA in predicting the path of formal roads. As can be seen by the LCPs calculated earlier, the cities along the Chinchaysuyu from Cuzco to Vilcashuaman were not always built where an energy-efficient least cost path would dictate.

The research in this thesis shows that it is extremely statistically unlikely that the Inka roads were built with strict energy-efficiency in mind and were instead built to connect cultural centers. If I were to expand on this research, I would do it in several ways. First, I would test to see if circuit theory improves this analysis. Second, I would perform separate LCAs between each city along the road in order to test if the roads were built in the most energy efficient corridor between each city, while still allowing connectivity. Finally, I would investigate the possible reasons for the locations of the cities along the road. Most cities appear to be located close to water and at high elevation. An investigation using GIS into the explanations for this pattern would expand on Hyslop's 1990 work on Inka settlement planning. As is, the location for the Chinchaysuyu road from Cuzco to Vilcashuaman is well-explained by cultural and historical factors present at the time of the road's construction. I believe LCA holds promise as a tool for identifying survey areas remotely; however, I believe it is insufficient for predicting formal road systems. However, I am satisfied with its ability to provide quantitative evidence for the role of culture in the construction of the Inka road system, particularly the Chinchaysuyu road as it runs from Cuzco to Vilcashuaman.

BIBLIOGRAPHY

Adamska, Anna, and Adam Michecsynski
1996. Towards Radiocarbon Chronology of the Inca State. Andes. Boletin de la Mision Arqueologica Andina 1: 35 - 58.

Adriaensen, F., J. P. Chardon, G. De Blust, et al.
2003. The Application of “least-Cost” Modelling as a Functional Landscape Model. Landscape and Urban Planning 64(4): 233–247.

Agurto Calvo, Santiago
1987. Estudios acerca de la construccion, arquitectura, y planeamiento incas. Camara Peruana de la Construccion, Lima.

Alcock, Susan E., John Bodel, and Richard J.A. Talbert.
2012. Introduction. *In* Highways, Byways, and Road Systems in the Pre-Modern World. Susan E. Alcock, John Bodel, and Richard J. A. Talbert, eds. Pp. 3-5. Wiley-Blackwell.

Bandelier, Adoph F.
1910. The Islands of Titicaca and Coati. Hispanic Society of America, New York.

Bandera, Damián de la
1557. “Relación general de la disposición y calidad de la provincia de Guamanga.” RGI, 176-180.

Barrenechea, Ricardo Ulloa
1962. Corazón de una historia. San José: Editorial Costa Rica.

Bauer, Brian S.
1992. The Development of the Inca State. University of Texas Press, Austin.

Bauer, Brian S.
1998. The Sacred Landscape of the Inca: The Cusco Ceque System. University of Texas Press, Austin.

Bauer, Brian S., and R. Alan Covey
2002. Processes of State Formation in the Inca Heartland (Cuzco, Peru). American Anthropologist 104(3): 846–864.

Bauer, Brian. S., and R. Alan Covey
2004. The Development of the Inca State. In Brian Bauer, Ancient Cuzco: Heartland of the Inca. pp. 71-90. Austin, University of Texas Press.

Bauer, Brian S.
2006. Suspension Bridges of the Inca Empire. *In* Andean Archaeology III. William H. Isbell and Helaine Silverman, eds. Pp. 468–493. Springer US.

Bauer, Brian S., Lucas C. Kellett, and Miriam Araoz Silva
2010. The Chanka: Archaeological Research in Andahuaylas (Apurimac), Peru. Monograph 68, Cotsen Institute of Archaeology Press, UCLA, Los Angeles.

Beck, Charlotte, Amanda K. Taylor, George T. Jones, et al.
2002. Rocks Are Heavy: Transport Costs and Paleoarchaic Quarry Behavior in the Great Basin. Journal of Anthropological Archaeology 21(4): 481–507.

Bell, Tyler, Andrew Wilson, and Andrew Wickham
2002. Tracking the Samnites: Landscape and Communications Routes in the Sangro Valley, Italy. American Journal of Archaeology 106(2): 169.

Beorchia Nigris, Antonio
1978. Análisis comparative, descripción de los santuarios de altura y conclusions provisorias en base a los antecedebtes conocidos hasta junto de 1978. *In* Revista del Centro de Investigaciones Arqueológicos de Alta Montaña. San Juan Argentina. Pp 11-16.
Besom, Thomas
2013. Inka Human Sacrifice and Mountain Worship: Strategies for Empire Unification. UNM Press.
Branting, S.A.
2004. Iron Age Pedestrians at Kerkenes Dag: An Archaeological GIS-T Approach to Movement and Transportation. Unpublished Ph.D. dissertation, State University of New York, Buffalo.
Bray, Tamara
2013. Water, Ritual and Power in the Inca Empire. *In* Latin American Antiquity 24(2): 1-30.
Bruhns, Karen Olsen
1994. Ancient South America. Cambridge University Press.
Bull, B.A.E
1946. South American Indians. *In* Handbook of South American Indians, Volume 2: The Andean Civilizations. Julian H. Steward, ed.
Cabello Valboa, Miguel
1951. Miscelanea antartica: una historia del Peru antiguo. Universidad Nacional Mayor de San Marcos, Instituto de Etnologia y Arqueologia, Lima.
Canseco, Maria Rostworowski de Diez
1999. History of the Inca Realm. Cambridge University Press.
Castro, Cristobal de, and Diego de Ortega Morejon
1974. Relaci6n y declaracion del modo que este valle de Chincha y sus comarcanos se governaven antes que oviese Ingas y despues q(ue) los vuo hasta q(ue) los Cristianos entraron en esta tierra. Historia y Cultura 8: 91-104. (Originally written 1558.)
Chataigner, C., and B. Gratuze
2014. New Data on the Exploitation of Obsidian in the Southern Caucasus (Armenia, Georgia) and Eastern Turkey, Part 2: Obsidian Procurement from the Upper Palaeolithic to the Late Bronze Age. Archaeometry 56(1): 48–69.
Chevallier, Raymond
1976. Roman Roads. Britannia 9: 497–497.
Chuvieco, Emilio, and Alfredo Huete, eds.
2009. Fundamentals of Satellite Remote Sensing. Har/Com edition. Boca Raton, FL: CRC Press.
Cieza de León, Pedro de
1922. La Crónica Del Perú: Con Tres Mapas. Los Grandes Viajes Clásicos, 24. Madrid: Calpe.
Cieza de León, Pedro de
1959. The Incas. 1st ed. Civilization of the American Indian Series, v. 53. Norman: University of Oklahoma Press.

Cieza de Leon, Pedro de
1967. El Senorio de los Incas: 2a. parte de la Cronica del Peru. Instituto de Estudios Peruanos, Lima. (Originally written 1551.)
Cieza de León, Pedro de
1973. El Señorío de Los Incas. 1. ed. Universo. Colección Autores Peruanos, 45. Lima: Editorial Universo.
Cieza de Leon, Pedro
2010. Travels of Pedro de Cieza de León, A.D. 1532–50 Contained in the First Part of His Chronicle of Peru.
Clarke, David L., ed.
1977. Spatial Archaeology. First Edition edition. London ; New York: Academic Press Inc.
Cobo, Bernabe
1979. History of the Inca Empire: An Account of the Indians' Customs and Their Origin, Together with a Treatise on Inca Legends, History, and Social Institutions, translated by Roland Hamilton. University of Texas Press, Austin.
Cobo, Bernabé
1990. Inca Religion and Customs. R. Hamilton, trans. and ed. Austin: University of Texas Press.
Collier, Peter
2002. The Impact on Topographic Mapping of Developments in Land and Air Survey: 1900-1939. *In* Cartography and Geographic Information Science 29:3. Pp. 155-174.
Conrad, Geoffrey W.
1977. Chiquitoy Viejo: An Inca Administrative Center in the Chicama Valley, Peru. Journal of Field Archaeology 4(1): 1–18.
Covey, R. Alan
2006. How the Incas Built their Heartland. Ann Arbor, University of Michigan Press.
Covey, R. Alan
2006. Chronology, Succession, and Sovereignty: The Politics of Inka Historiography and Its Modern Interpretation. Comparative Studies in Society and History 48(1): 166-99.
Crawford, O. G. S.
1923. Air Survey and Archæology. The Geographical Journal 61(5): 342–360.
Dalakoglou, Dimitris, and Penny Harvey
2012. Roads and Anthropology: Ethnographic Perspectives on Space, Time and (Im)Mobility. Mobilities 7(4): 459–465.
D’Altroy, Terrence N. and Katharina Schrieber
2004. Andean Empires. *In* Andean Archaeology. Helaine Silverman, ed. Pp 255-279.
D’Altroy, Terrence N.
2015. The Incas. 2nd ed. Chichester: Wiley Blackwell Publishing.
Davies, Hugh E.H.
1998. Designing Roman Roads. Britannia 29: 1–16.
DeLeonardis, Lisa
2011. Itinerant Experts, Alternative Harvests: Kamayuq in the Service of Qhapaq and Crown. Ethnohistory 58(3): 445–489.

Deloche, J.
1993. Transport and communications in India prior to steam locomotion: Volume I: land transport (Vol. 1). Oxford University Press, USA.
Dettelbach, Michael
2008. Alexander Von Humboldt. *In* Guide to Documentary Sources for Andean Studies, 1530-1900. Pillsbury, Joanne, and Center for Advanced Study in the Visual Arts (U.S.), eds. Pp. 307-308. University of Oklahoma Press.
Diez de Betanzos, Juan de
1996. Narrative of the Incas. 1st ed. Austin: University of Texas Press.
Doyle, Michael W.
1986. Empires. Cornell University Press.
Duviols, Pierre
l979. Datacion, paternite et ideologique de la "Declaracion de los Quipucamayos a Vaca de Castro." In Les cultures iberiques en devenir, essais publies en homenage a la memoire de Marcel Bataillon (1895 -1977), pp. 583 - 91. La Fondation Singer-Polignac, Paris.
Enock, Charles Reginald
1908. Peru: Its Former and Present Civilization, History and Existing Conditions, Topography and Natural Resources, Commerce and General Development. Unwin.
Erdmann, León Strube
1963. Vialidad imperial de los incas desde Colombia hasta Chile central y sur de Mendoza (Argentina) con inclusión de sus proyecciones orientales. Córdoba: Dirección General de Publicaciones.
Espinoza Soriano, Waldemar
1969. Lurinhuaila de Huacjra; un ayllu y un curacazgo huanca. Huancayo, Perú: Casa de la Cultura [de Junín].
ESRI Developer Network.
2011. Cost Distance.
http://edndoc.esri.com/arcobjects/9.2/net/shared/geoprocessing/spatial_analyst_tools/cost_distance.htm
Falcon, Francisco
1946. Representacion hecha por el Licenciado Falcon en concilio provincial sobre los danos y molestias que se hacen a los indios. In Los Pequefios Grandes Libras de Historia Americana, edited by Francisco A. Loayza. Series 1, vol. 10, pp. 121-64. D. Miranda, Lima. (Originally written 1567.)
Fejos, Paul
1944. Archaeological Exploration in the Cordillera Vilcabamba, Southeastern Peru. Viking Fund Publications in Anthropology 3. New York.
Ferris, Harry Burr, and Luther Townsend Nelson
1916. The Indians of Cuzco and the Apurimac. Pub. for the American Anthropological Association, the New Era Printing Company.
Forbes, R J.
1964. Notes on the History of Ancient Roads and Their Construction: 2. Unrev : Ed. Amsterdam: Adolf M. Hakkert. Print,

Frisancho, A. Roberto, and Paul T. Baker
1970. Altitude and Growth: A Study of the Patterns of Physical Growth of a High Altitude Peruvian Quechua Population. American Journal of Physical Anthropology 32(2): 279–292.
Garcilaso de la Vega, El Inca
1966. Royal Commentaries of the Incas, translated with an introduction by Harold V. Livemore. University of Texas Press. Austin. (Originally written 1609.)
Gibbon, Lardner
1854. Exploration of the Valley of the Amazon : Made under Direction of the Navy Department by Wm. Lewis Herndon and Lardner Gibbon. Washington : Robert Armstrong, public printer. http://archive.org/details/valleyoftheamazo01hern, accessed March 7, 2015.
Goodchild, M.F. and D.G. Janelle, eds.
2004. Spatially Integrated Social Science. New York: Oxford University Press.
Guamán Poma de Ayala, Felipe, and Arthur Posnansky
1944. La obra de Phelipe Guaman Poma de Ayala "Primer nueva corónica y buen gobierno" (escrita entre 1584 y 1614). La Paz: Editorial del Instituto Tihuanacu de Antropología, Etnografía y Prehistoria.
Gupta, A. and Ferguson, J.
1992. Beyond 'culture': space, identity, and the politics of difference. Cultural Anthropology, 7(1): 6–23.
Gupta, A. and Ferguson, J.
1997. Culture, power, place: explorations in critical anthropology, Durham, NC: Duke University Press.
Gutierrez, Gerardo
2015. Personal Communication via e-mail on the route of the road from Cuzco to Vilcashuaman.
Hamilton, Roland
1996. Introduction. In Narrative of the Incas, edited by Roland Hamilton and Dana Buchanan, pp. ix-xiv. University of Texas Press, Austin.
Hauser, Kitty
2008. Bloody Old Britain: O.G.S. Crawford and the Archaeology of Modern Life. London: Granta UK.
Hayashida, Frances M.
1999. Style, Technology, and State Production: Inka Pottery Manufacture in the Leche Valley, Peru. Latin American Antiquity 10(4): 337–352.
Hayashida, Frances M.
2006. The Pampa de Chaparrí: Water, Land, and Politics on the North Coast of Peru. Latin American Antiquity 17(3): 243–263.
Hayashida, Frances M.
2008. Ancient beer and modern brewers: Ethnoarchaeological observations of chicha production in two regions of the North Coast of Peru. Journal of Anthropological Archaeology 27: 161-174.

Heffernan, Kenneth J.
1989. Limatambo in Late Prehistory: Landscape Archaeology and Documentary Images of Inca Presence in the Periphery of Cuzco. Unpublished PhD dissertation, Department of Anthropology, Australian National University, Canberra.
Heilman, Jaymie
2010. Before the Shining Path: Politics in Rural Ayacucho, 1895-1980. Stanford University Press.
Hemming, John
1970. The Conquest of the Incas. New York: Mariner Books.
Hendrickson, Mitch
2010. Historic Routes to Angkor: development of the Khmer road system (ninth to thirteenth centuries AD) in mainland Southeast Asia. *In* Antiquity 84. Pp 480-496.
Higgins, James
2005. Lima: A Cultural History. Oxford University Press.
Hiltunen, Juhua and Gordon F. McEwan
2004. Knowing the Inca Past. In *Andean Archaeology*. Helaine Silverman, ed. pp. 237-279.
Holguín, Diego González
1952. Gramatica Y Arte Nueva Dela Lengua General de Todo El Peru, llamada Lengua Qquichua, O Lengua Del Inca. Vaduz: Cabildo.
Howey, Meghan C. L.
2007. Using Multi-Criteria Cost Surface Analysis to Explore Past Regional Landscapes: A Case Study of Ritual Activity and Social Interaction in Michigan, AD 1200–1600. Journal of Archaeological Science 34(11): 1830–1846.
Huckleberry, Gary, and Brian R. Billman
2003. Geoarchaeological Insights Gained from Surficial Geologic Mapping, Middle Moche Valley, Peru. Geoarchaeology 18(5): 505–521.
Humboldt, Alexander von
1814. Researches, Concerning the Institutions & Monuments of the Ancient Inhabitants of America: With Descriptions & Views of Some of the Most Striking Scenes in the Cordilleras! Longman, Hurst, Rees, Orme & Brown, J. Murray & H. Colburn.
Hyland, Sabine
2011. Gods of the Andes: An Early Jesuit Account of Inca Religion and Andean Christianity. Latin American Originals 6. Pennsylvania State University Press, University Park.
Hyslop, John
1984. Introduction. *In* The Inka Road System. Pp. 12-19. Academic Press.
Hyslop, John
1990. Inka Settlement Planning. University of Texas Press.
Jenkins, David
2001. A Network Analysis of Inka Roads, Administrative Centers, and Storage Facilities. Ethnohistory 48(4): 655–687.
Janusek. John W
2008. Ancient Tiwanaku. Cambridge University Press, Cambridge.
Jennings, Justin
2010. Globalizations and the Ancient World. Cambridge University Press, Cambridge.

Jennings, Justin, and Brenda J. Bowser, eds.
2009. Drink, Power, and Society in the Andes. University Press of Florida, Gainesville.
Julien, Catherine J.
1982. Inca Decimal Administration in the Lake Titicaca Region. In *The Inca and Aztec States, 1400-1800: Anthropology and History*. George A. Collier, Renato I. Rosaldo, and John D. Wirth, eds. pp. 119-51. New York.
Julien, Catherine J.
1983. Hatunqolla, a View of Inca Rule from the Lake Titicaca Region. University of California Press.
Julien, Catherine J.
1988. How Inca Decimal Administration Worked. Ethnohistory 35(3): 257–279.
Julien, Catherine J.
2000. Reading Inca History. University ofIowa Press, Iowa City.
Julien, Catherine
2007. War and Peace in the Inca Heartland. *In* War and Peace in the Ancient World. Kurt A. Raaflaub, ed. Pp. 329–347. Blackwell Publishing Ltd.
Julien, Catherine
2012. The Chinchaysuyu Road and the Definition of an Inca Imperial Landscape. *In* Highways, Byways, and Road Systems in the Pre-Modern World. Susan E. Alcock, John Bodel, and Richard J. A. Talbert, eds. Pp. 147–167. Wiley-Blackwell.
Kantner, John
1997. Evaluating Prehistoric Chaco Anasazi Roadways using Geographic Information Systems Technology. Manuscript submitted to Expedition Magazine.
Kellett, Lucas
2010. Chanka Settlement Ecology: Hilltop Sites, Land Use and Warfare in Late Prehispanic Andahuaylas, Peru. PhD dissertation. University of New Mexico.
Kolata, Alan L.
2012. Ancient Inca. Case Studies in Early Societies. Cambridge [England]; New York: Cambridge University Press.
Kosiba, Steven B.
2010. Becoming Inka: The Transformation of Political Place and Practice during Inka State Formation (Cusco, Peru). PhD dissertation, Dept. of Anthropology, University of Chicago.
La Lone, Darrell
1982. The Inca as a Nonmarket Economy: Supply on Command versus Supply and Demand. Academia.edu.
http://www.academia.edu/885136/The_Inca_as_a_nonmarket_economy_Supply_on_command_versus_supply_and_demand, accessed March 7, 2015.
Lasaponara, Rosa, and Nicola Masini, eds.
2012. Satellite Remote Sensing, vol.16. Remote Sensing and Digital Image Processing. Dordrecht: Springer Netherlands. http://link.springer.com/10.1007/978-90-481-8801-7, accessed March 7, 2015.
Magli, Giulio, Eugenio Realini, Mirko Reguzzoni, and Daniele Sampietro
2014. High-Precision GPS Survey of Via Appia: Archaeoastronomy-related Aspects. *In* Mediterranean Archaeology and Archaeometry 14(3): 55-65. Greece.

MacCormack, Sabine
1991. Religion in the Andes: Vision and Imagination in Early Colonial Peru. Princeton University Press, Princeton, NJ.
Malville, Nancy J.
1999. Porters of the Eastern Hills of Nepal: Body Size and Load Weight. American Journal of Human Biology : The Official Journal of the Human Biology Council 11(1): 1–11.
Mantha, Alexis
2012. 10 Shifting Territorialities under the Inka Empire: The Case of the Rapayán Valley in the Central Andean Highlands. Archeological Papers of the American Anthropological Association 22(1): 164–188.
Margary, Ivan Donald
1955. Roman roads in Britain.
McCoy, Mark D., and Thegn N. Ladefoged
2009. New Developments in the Use of Spatial Technology in Archaeology. Journal of Archaeological Research 17(3): 263–295.
McDonald, I.
1961. Statistical Studies of Recorded Energy Expenditure of Man. Nutrition Abstracts and Reviews 31(3): 739-762.
McEwan, Gordon E.
2006. The Incas: New Perspectives. ABC-CLIO, Santa Barbara, CA.
Morley, Iain, and Colin Renfrew, eds.
2010. The Archaeology of Measurement: Comprehending Heaven, Earth and Time in Ancient Societies. Cambridge, New York: Cambridge University Press.
Morris, Craig, and Donald Thompson
1985. Huánaco Pampa: An Inca City and Its Hinterland. London: Thames and Hudson.
Morris, Craig and Adriana Von Hagen
2011. The Incas: Lords of the Four Quarters. London: Thames and Hudson.
Moseley, Michael E.
2001. The Incas and Their Ancestors. Revised Edition. London: Thames and Huson.
Moseley, Michael Edward, and Alana Cordy-Collins, eds.
1990. The Northern Dynasties: Kingship and Statecraft in Chimor: A Symposium at Dumbarton Oaks, 12th and 13th October 1985. Dumbarton Oaks Research Library and Collection, Washington, DC.
Moseley, Michael E.
2001. The Incas and Their Ancestors: The Archaeology of Peru. Revised Second Edition edition. New York, NY: Thames & Hudson.
Murra, John V.
1980. The Economic Organization of the Inka State. JAI Press, Greenwich, CT. (Doctoral dissertation originally written 1956.)
Murra, John V.
1982. The Mit'a Obligations of Ehtnic Groups to the Inka State. In The Inca and Aztec States, 1400-1800: Anthropology and History. George A. Collier, Renato I. Rosaldo, and John D. Wirht, eds. Pp 237-262. New York: Academic Press.

Murra, John V.
1984. Andean Societies before 1532. In The Cmabridge History of Latin America. Vol. 1, Colonial Latin America. Leslie Bethell, ed. Pp. 59-90. Cambridge: Cambridge University Press.

Murúa, Fray Martin de
1986. Historia general del Peru., edited by Manuel Ballesteros. Historia 16, Madrid. (Originally written c. 1605.)

National Aeronautics and Space Administration
2004. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). Jet Propulsion Laboratory. California Institute of Technology. http://asterweb.jpl.nasa.gov/. Accessed 6 March 2015.

National Aeronautics and Space Administration
2005. Shuttle Radar Topography Mission. Jet Propulsion Laboratory. California Institute of Technology. http://www2.jpl.nasa.gov/srtm/. Accessed 6 March 2015.

National Museum of the American Indian
2013. Inka Road Research. http://blog.nmai.si.edu/main/2013/09/inka-road-research-2013-1.html

Needham, Joseph
1970. Science and Civilisation in China. Cambridge University Press.

Newhard, James M. L., Norm Levine, and Allen Rutherford
2008. Least-Cost Pathway Analysis and Inter-Regional Interaction in the Göksu Valley, Turkey. Anatolian Studies 58: 87–102.

Nordenskiöld, Erland
1924. The Ethnography of South-America Seen from Mojos in Bolivia.

Ortiz de Zúñiga, Iñigo
1967. Visita de la provincia de León de Huánuco en 1562. Huánuco, Perú: Universidad Nacional Hermilio Valdizán, Facultad de Letras y Educación.

Pachacuti Yamqui Salcamaygua, Joan de Santa Cruz
1993. Relacion de antigiiedades deste Reyno del Piru. Estudio etnohistorico y lingiiistico de Pierre Duviols y Cesar Itier. Institut Francais d'Etudes Andines, Centro de Estudios Regionales Andinos "Bartolome de Las Casas," Cuzco. (Originally written 1613.)

Pandolf, K.B., G.B. Givoni, and R.F. Goldman
1977. Predicting Energy Expenditure with Loads While Standing or Walking Very Slowly. Journal of Applied Physiology 43(4): 577-581.

Parcak, Sarah H.
2009. Satellite Remote Sensing for Archaeology. Taylor & Francis.

Parssinen, Martti
1992. Tawantinsuyu: The Inca State and Its Political Organization. Societas Historica Finlandiae, Helsinki.

Pease G. Y., Franklin
1995. Las Cronicas y los Andes. Pontificia · Universidad Catolica del Peru, Lima.

Pillsbury, Joanne, ed.
2001. Moche Art and Archaeology in Ancient Peru. National Gallery of Art, Washington, DC.

Polo de Ondegardo, Juan
1917. La Relacion del linaje de los Incas y como extendieron ellos sus conquistas. In Coleccion de libros y documentos referentes a la historia del Peru, edited by Horacio H. Urteaga, vol. 4, pp. 45 - 94. Sanmarti, Lima. (Originally written 1567.)
Polo de Ondegardo, Juan
1940. Informe del Licenciado Juan Polo de Ondegardo al Licenciado Briviesca de Munatones sobre la perpetuidad de las encomiendas en el Peru. Revista Historica 13: 128-96. (Originally written 1561.)
Quilter, Jeffrey, and Luis Jaime Castillo B., eds.
2010. New Perspectives on Moche Political Organization. Dumbarton Oaks, Washington, DC.
Raaflaub, Kurt A., and Richard J. A. Talbert, eds.
2010. Geography and Ethnography: Perceptions of the World in Pre-Modern Societies. Malden: Wiley-Blackwell.
Rabus, B., M. Eineder, A. Roth, and R. Bamler
2003. The Shuttle Radar Topography Mission – A New Class of Digital Elevation Models Acquired by Spaceborne Radar. ISPRS Journal of Photogrammetry and Remote Sensing 57(4):241-262.
Racoviteanu, A.E., W.F. Manley, Y. Arnaud, and M.W. Williams
2007. Evaluating Digital Elevation Models for Glaciologic Applications: An Example from Nevado Coropuna, Peruvian Andes. Global and Planetary Change 59:110-125.
Rademaker, Kurt, David A. Reid, and Gordon R.M. Bromley
2012. Connecting the Dots: Least Cost Analysis, Paleography, and the Search for Paleoindian Sites in Southern Highland Peru. In Least Cost Analysis of Social Landscapes: Archaeological Case Studies. White, Devin A., and Sarah L. Surface-Evans, eds. Pp. 32-45. Ann Arbor: University of Utah Press.
Regal, Alberto
1936. Los caminos del inca en el antiguo Peru. Sanmartí y cía., s.a.
Regalado de Hurtado, Liliana
1996. La Sucesión Incaica: Aproximación Al Mando Y Poder Entrelos Incas a Partir de La Crónica de Betanzos. 2. ed., corr. y aum. Lima, Perú: Pontificia Universidad Cátolica del Perú, Fondo Editorial.
Robertson, Elizabeth C., Jeffery D. Seibert, Deepika C. Fernandez, and Marc U. Zender, eds.
2006. Space and Spatial Analysis in Archaeology. Calgary: University of New Mexico Press.
Rowe, John H.
1944. An Introduction to the Archaeology of Cuzco. Peabody Museum of American Archaeology and Ethnology Papers 27, no. 2. Cambridge, MA.
Rowe, John H.
1946. Inca Culture at the Time of the Spanish Conquest. In *Handbook of South American Indians*. Bureau of South American Ethnology, Buletin 143, vol. 2. J. Steward, ed., pp. 183-330. Washington, DC: Smithsonian Institution Press.
Rowe, John H.
1958. The Age Grades of the Inca Census. In Miscellanea Paul Rivet Octogenario Dicata II. XXXI Congreso Internacional de Americanistas, pp. 499-522. Universidad Nacional Autónoma de Mexico, Mexico.

Rowe, John H.
1985. Probanza de los Incas nietos de conquistadores. Historica 9(2): 193-245.
Ryden, Stig
1947. Archaeological Researches in the Highlands of Bolivia. Elanders Boktryckeri Aktiebolag, Goteborg.
Sabloff, Jeremy A. and William L. Rathje
1975. Cozumel's Place in Yucatan Culture History. *In* Changing Pre-Columbian Commercial Systems: Cozumel, Mexico. Jeremy A. Sabloff and William L Rathje, eds. PP 12-28. Harvard University, Cambridge, MA.
Santee, W.R., W.F. Allison; L.A. Blanchard, and M.G. Small
2001. A Proposed Model for Load Carriage on Sloped Terrain. Aviation, Space and Environmental Medicine 72(6): 562-566.
Sarmiento de Gamboa, Pedro
1907. History of the Incas, trans. and ed. by Clements R. Markham, published for the Hakluyt Society, 2nd series, no. 22, Cambridge. (reprinted by Dover Publications, 1999. Originally written 1572).
Sarmiento de Gamboa, Pedro
2007. The History of the Incas, translated and edited by Brian S. Bauer and Vania Smith. University of Texas Press, Austin. (Originally written 1572.)
Schreiber, Katharina J.
1987. Conquest and Consolidation: A comparison of the Wari and Inka Occupations of a Highland Peruvian Valley. American Antiquity, Vol. 52, No. 2. pp 266-284.
Schreiber, Katharina J.
1992. Wari Imperialism in Middle Horizon Peru. Museum of Anthropology, University of Michigan, Ann Arbor.
Schreiber, Katharina J.
2001. The Wari Empire of Middle Horizon Peru: The Epistemological Challenge of Documenting an Empire without Documentary Evidence. In Empires, edited by Susan E. Alcock, Terence N. D'Altroy, Kathleen D. Morrison, and Carla M. Sinopoli, pp. 70 - 92. Cambridge University Press, Cambridge.
Shimada, Izumi
1994. Pampa Grande and the Mochica Culture. University of Texas Press, Austin.
Shinoda, Ken-ichi, Noboru Adachi, Sonia Guillen, and Izumi Shimada
2006. Mitochondrial DNA Analysis of Ancient Peruvian Highlanders. American Journal of Physical Anthropology l31(1): 98-107. Online at http://onlinelibrary. wiley.com/doi/l0.1002/ajpa.20408/abstract (accessed December 3, 2014).
Silverblatt, Irene, and American Council of Learned Societies
1987. Moon, Sun, and Witches Gender Ideologies and Class in Inca and Colonial Peru. Princeton, N.J: Princeton University Press.
Sinopoli, Carla M.
1994. The Archaeology of Empires. Annual Review of Anthropology. Vol. 23. pp 159-180.
Smith, Michael E.
2001. The Aztec Empire and the Mesoamerican World System. In Empires, edited by Susan E. Alcock, Terence N. D'Altroy, Kathleen D. Morrison, and Carla M. Sinopoli, pp. 70 - 92. Cambridge University Press, Cambridge.

Sobrino, José A., Juan C. Jiménez-Muñoz, Lee Balick, et al.
2007. Accuracy of ASTER Level-2 Thermal-Infrared Standard Products of an Agricultural Area in Spain. Remote Sensing of Environment 106(2): 146–153.
Soule, R.G. and R.F. Goldman
1972. Terrain Coefficients for Energy Cost Prediction. Journal of Applied Physiology 32(5): 706-708.
Taliaferro, Matthew S., Bernard A. Schriever, and M. Steven Shackley
2010. Obsidian Procurement, Least Cost Path Analysis, and Social Interaction in the Mimbres Area of Southwestern New Mexico. Journal of Archaeological Science 37(3): 536–548.
Tighe, M. Lorraine and Drew Chamberlain
2009. Accuracy Comparison of the SRTM, ASTER, NED, NEXTMAP® USA Digital Terrain Model over Several USA Study Sites. ASPRS/MAPPS 2009 Fall Conference. November 16-19, 2009. San Antonia, Texas. http://www.asprs.org/a/publications/proceedings/sanantonio09/Tighe_2.pdf. Accessed 6 December 2014.
Urton, Gary
1990. The History of a Myth: Pacariqtambo and the Origin of the Inkas. University of Texas Press, Austin.
Vaca de Castro, Cristóbal
1908. Ordenanzas de tambos, distancias de unos a otros, modo de cargar los indios y obligaciones de las justicias respectivas hechas en la ciudad del Cuzco en 31 Mayo de 1543. Revista Histórica, tomo III, pp. 427-492. Instituto Histórico del Perú, Lima.
Van de Guchte, Maarten J. D.
1990. "Carving the World": Inca Monumental Sculpture and Landscape. PhD dissertation, Department of Anthropology, University of Illinois at Urbana-Champaign. University Microfilms, Ann Arbor, MI.
Walker, John H.
2012. Recent Landscape Archaeology in South America. Journal of Archaeological Research 20(4): 309–355.
White, Devin A.
2012. Prehistoric Trail Networks of the Wester Papaguería: A Multi-faceted Least Cost Graph Theory Analysis. *In* Least Cost Analysis of Social Landscapes: Archaeological Case Studies. White, Devin A., and Sarah L. Surface-Evans, eds. Pp. 188-206. Ann Arbor: University of Utah Press.
Witcher, R.E.
1998. ‘Roman roads: phenomenological perspectives on roads in the landscape’ in TRAC 97: proceedings of the Seventh Annual Theoretical Roman Archaeology Conference, which formed part of the Second International Roman Archaeology Conference, University of Nottingham, April 1997. OxfordL Oxbow Books, pp. 60-70.
Wolfgang von Hagen, Victor
1959. The Incas of Pedro de Cieze de Leon. Norman: University of Oklahoma Press.
Zuidema, R. Tom
2008. Damián de la Bandera. *In* Guide to Documentary Sources for Andean Studies, 1530-1900. Pillsbury, Joanne, and Center for Advanced Study in the Visual Arts (U.S.), eds. Pp. 71-73. University of Oklahoma Press.